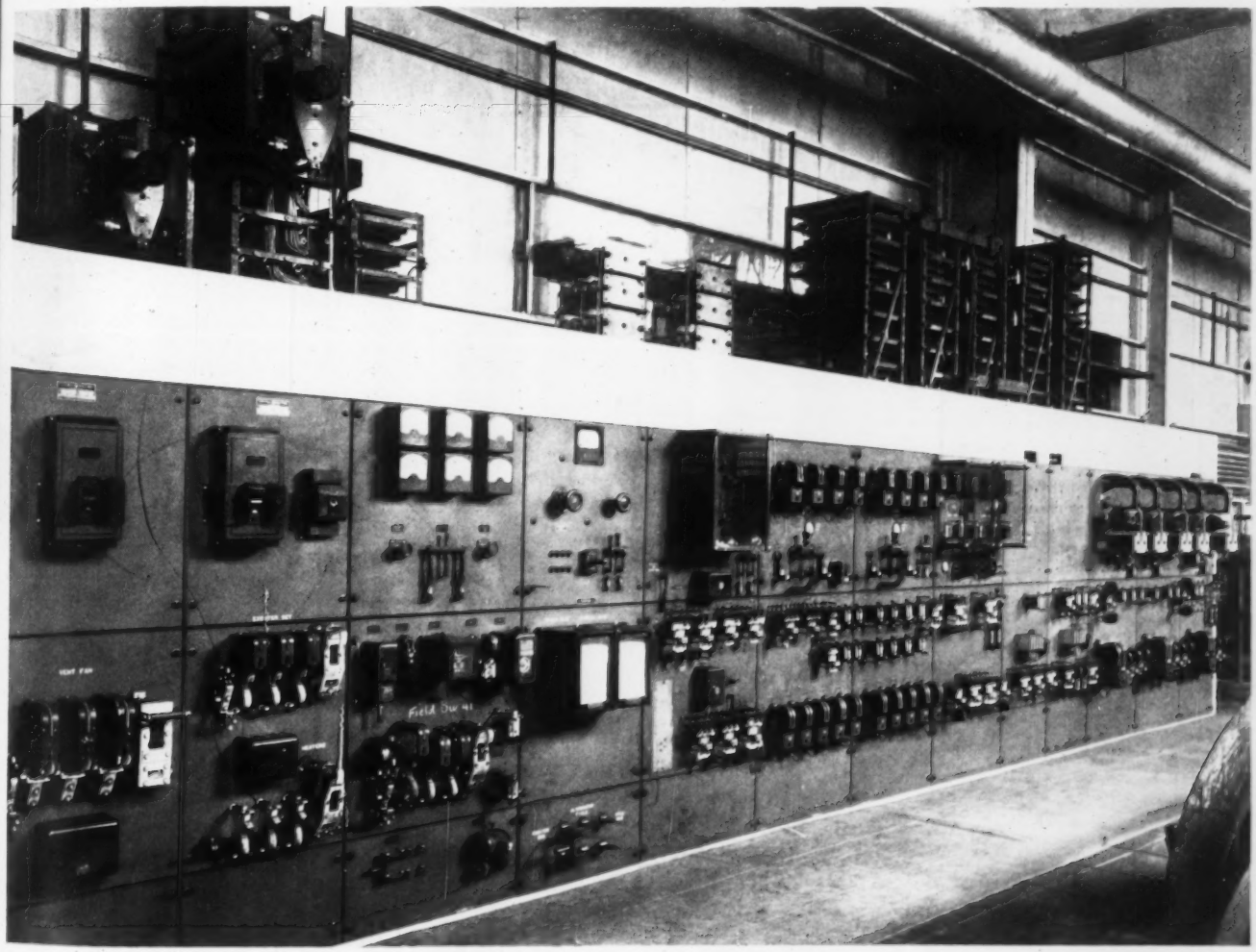
INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT AND CONTROL

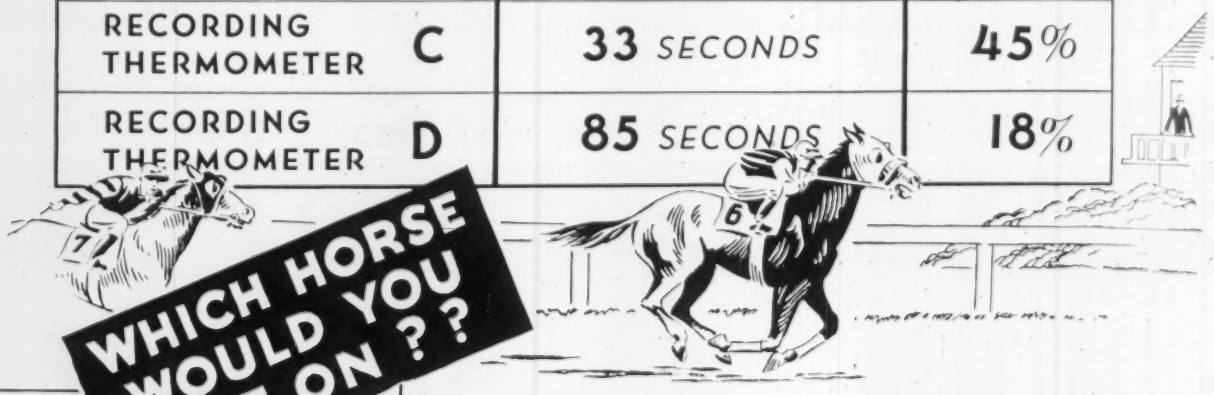
Volume 8 DECEMBER 1935 Number 12



ROLLING MILL INSTRUMENTATION: Reversing motor controls, automatic screwdown and sheet gage control, etc.
Courtesy Jones & Laughlin Steel Corporation

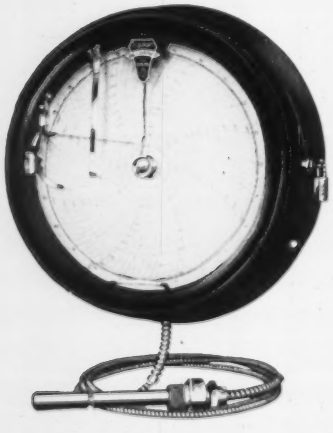
Responsiveness

RESPONSIVENESS CHART		
INSTRUMENT	TIME TAKEN TO COVER EQUAL PORTION OF CHART SCALE	PER CENT DIFFERENCE
FOXBORO RECORDING THERMOMETER	15 SECONDS	100%
RECORDING THERMOMETER A	32 SECONDS	47%
RECORDING THERMOMETER B	42 SECONDS	37%
RECORDING THERMOMETER C	33 SECONDS	45%
RECORDING THERMOMETER D	85 SECONDS	18%



WHICH HORSE WOULD YOU BET ON ??

BOTH horses are fast. The divisions on an ordinary stop watch are not fine enough to clock the 1/100th of a second between them. Yet one horse wins by a nose and earns the prize money. Which horse would you put your money on?



The response of a good Recording Thermometer is fast. But, like race horses, all makes of Thermometers do not respond alike.

Five Recording Vapor Pressure Type Thermometers of different manufacture were recently tested for responsiveness. The above chart shows the results of this test—the time taken for each instrument to cover the same portion of its chart scale.

All instruments were comparable as to chart range, size of bulb, filling medium, connecting tubing, etc. Each instrument was tested under identical conditions.

The nearest competitor took over twice as long to respond as did the Foxboro Thermometer. Yet all of these instruments were good thermometers.

Responsiveness (like accuracy, durability and simplicity) is one of the important characteristics of a Foxboro Recording Thermometer. Here is an instrument that is built to give good service for twenty years and more, for engineers who insist on putting their money on a winner.

The Foxboro Company
46 Neponset Ave.
Foxboro, Mass. U. S. A.
Branches in 20 Principal Cities

FOXBORO
REG. U. S. PAT. OFF.
THE COMPASS OF INDUSTRY

COMPARE THE NEW FOXBORO RECORDING THERMOMETER

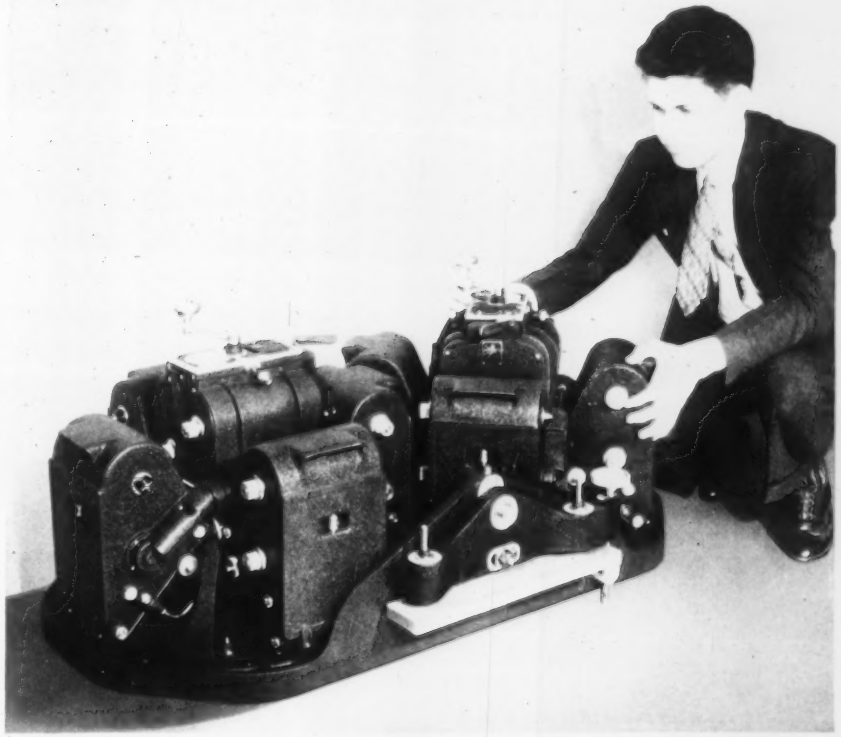
★

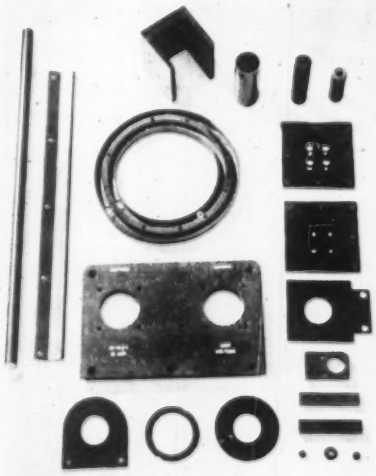
The World's Largest Camera

relies on Bakelite Materials

A 275-POUND, ten-lens compound aerial camera has recently been developed by the Fairchild Aerial Camera Company of Woodside, Long Island. Capable of photographing 760 square miles of territory at a single exposure, it represents a major contribution to topographic science as the first practical means of charting vast unmapped sections of the earth's surface.

In the assembly of this intricate precision instrument, parts formed from Bakelite Materials are relied upon to perform numerous functions of high responsibility. Because of their unusual combination of strength, durability, electrical insulation, ease and accuracy of forming, and high resistance to oil and moisture, Bakelite Molded and Bakelite Laminated were selected for the making of shutter bus bar housings; lamp socket plates; operating switch insulators; transformer, condenser and relay terminal panels; and other vital parts.





Some of the Bakelite Molded and Laminated parts used in the Fairchild Camera.

Today a steadily increasing variety of scientific instruments and other products are employing Bakelite Materials to meet similar needs for greater versatility and dependability. Manufacturers of instruments and other precision products can benefit from a thorough understanding of the properties and characteristics of these improved modern materials. Write for our informative booklets 37M, "Bakelite Molded" and 37L, "Bakelite Laminated".

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THE MATERIAL OF A THOUSAND USES

INSTRUMENTS

THE MAGAZINE of MEASUREMENT and CONTROL

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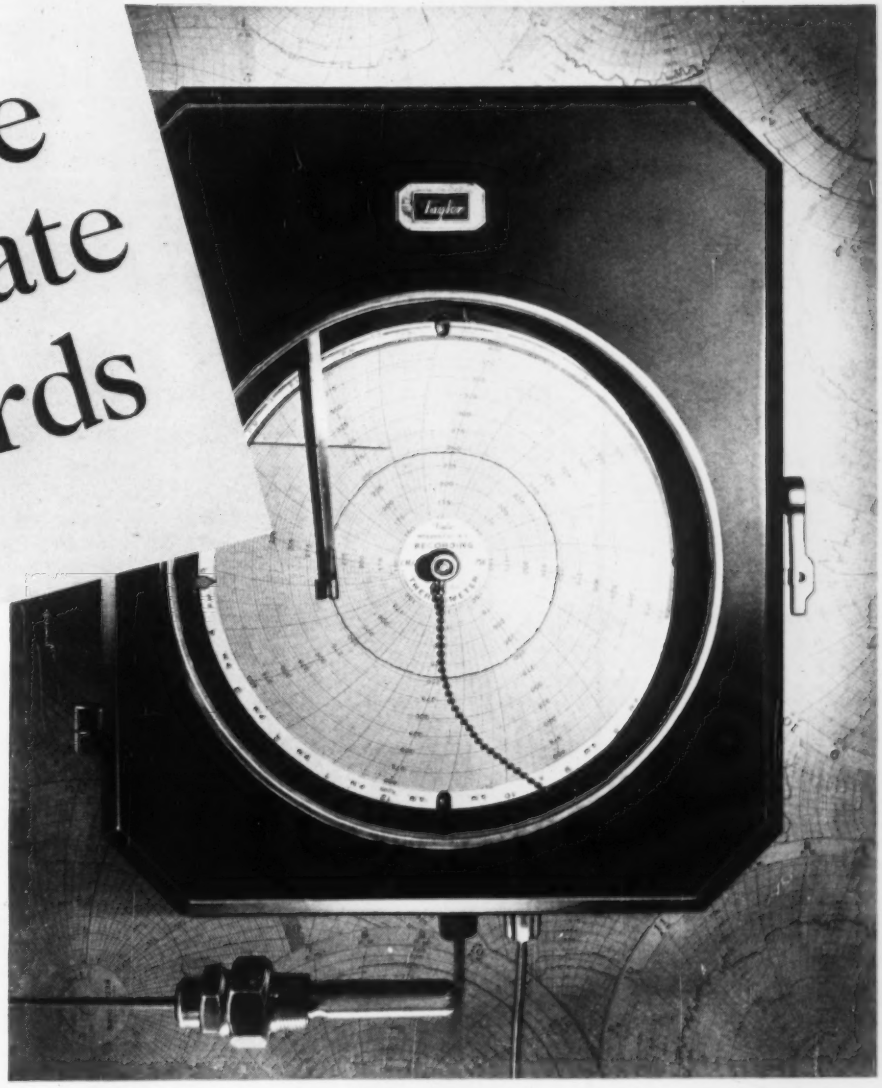
MODERN TAYLOR RECORDING THERMOMETER. For applications within minus 100° F. and plus 1000° F. Face- or flush-mounted cases. Dust-proof and moisture-proof. *Taylor Recording Pressure Gauges* are similar in appearance. Interchangeable tube systems make conversion from Pressure Gauge to Recording Thermometer easy.

Write accurate records

for today and tomorrow



...WITH TAYLOR RECORDING THERMOMETERS AND PRESSURE GAUGES

THE modern Taylor Recording Instrument assures a more accurate record of temperature and pressure than was obtainable before. Its efficient and economical operation guards today's profits against waste and high production costs. And it makes future processing a clearer picture in the light of past records.

Taylor Recording Instruments are designed to meet the most exacting requirements in the chemical industry. They are built to last longer. A simplified and refined mechanism, light in weight but sturdy and durable, and practically frictionless, instantaneously translates temperature or pressure into pen arm action.

The construction of Taylor Recording Instruments makes them adaptable to any temperature or pressure need. Temperature Recorders, for example, are of three types—mercury-, gas-, and vapor-actuated. With the mercury-actuated type is available one of the most important aids to accuracy ever developed. This is Taylor Accuratus Tubing, an exclusive, patented product that automatically compensates for all temperature differences surrounding the tubing between bulb and instrument. It assures a true bulb temperature record. It permits installations of the recorder at unusual distances from the bulb.

Write for Taylor Catalog 68J for further data on Temperature Recorders. Get Catalog 68JF for more information on Taylor Recording Pressure Gauges.

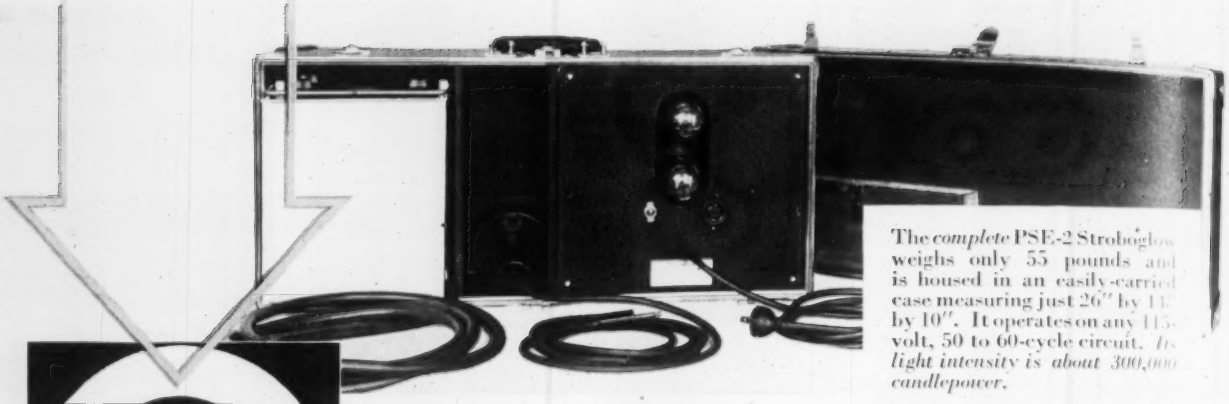
For first-hand information on these and all other Taylor Instruments for controlling temperature, pressure, rate of flow or liquid level, ask a Taylor Representative to come and discuss their application with you. Address Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada. Manufacturers in Great Britain—Short & Mason, Ltd., London, England.

Taylor

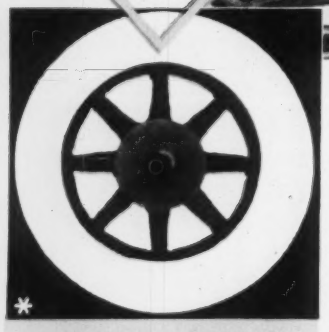
Indicating Recording Controlling

TEMPERATURE, PRESSURE *and* **FLOW INSTRUMENTS**

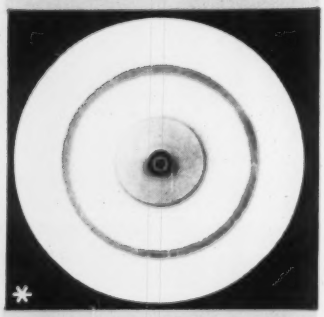
STOP! LOOK! ANALYZE!



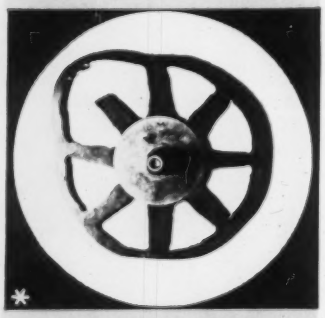
The *complete* PSE-2 Stroboglow weighs only 55 pounds and is housed in an easily-carried case measuring just 26" by 14" by 10". It operates on any 115-volt, 50 to 60-cycle circuit. *Its light intensity is about 300,000 candlepower.*



Flywheel at rest



Flywheel rotating 1800 r.p.m.



Rotating flywheel under Stroboglow

*Unretouched

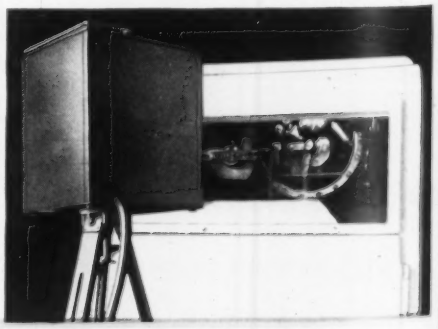
Above left is an experimental sponge-rubber flywheel *at rest.* You can examine easily every detail. Perhaps you can even see that the spoke in the 11 o'clock position is cut. What happens to this wheel when it revolves at 1800 r.p.m.? To the unaided eye, the revolving flywheel is only a blur. Analysis is impossible. But to the bottom left is the same *revolving* wheel under the new Westinghouse Type PSE-2 Stroboglow.

Although the wheel is rotating rapidly (1800 r.p.m.), it appears motionless. Every effect of centrifugal force is shown accurately and clearly. Visual analysis of strains and stresses can be conducted easily, quickly, *and accurately.*

This new stroboglow will "stop" any moving object having a periodic movement not exceeding 30,000 cycles per minute. A few of the many typical movements that can be analyzed quickly and profitably with the new PSE-2 are: rotational and impact vibration, cam and cam roller action, valve and valve spring movement, propeller vibrations, splash oil systems, and the sequence of practically any rapidly moving machinery.

The PSE-2 Stroboglow sets a new high standard for this type of equipment. Light in weight and easily carried, it assures images of almost unbelievable sharpness—so clear, distinct, and steady that photographs can be taken easily under its 300,000 candlepower light—a light many times more intense than any previous stroboglow possessed.

For detailed information, ask for Catalog Section 43-756. R 57060



Analyzing the splash oil system of a Westinghouse Refrigerator

SINCE 1888

METERS INSTRUMENTS RELAYS

Westinghouse

GREATER CONVENIENCE SUSTAINED ACCURACY

DOUBLE-RANGE OHMMETER TEST UNIT

TRIPLE-RANGE OHMMETER TEST UNIT

D-C. VOLT-OHMMETER TEST UNIT

Mark NEW Ⓦ TEST UNITS

For practically all testing of electrical apparatus—assembled or on the production line—a new Westinghouse Portable Test Unit can do the job quicker, easier, and more accurately than any comparative device.

Take as an example the multi-range Unit shown above. To use any one of its eleven ranges, you turn only the convenient range selector—there are no thumb screws to loosen and tighten—no resistors to hook up or take out of the circuit.

All accessory equipment for using any one of the ohm, volt, or milliampere ranges, a-c. or d-c., is contained in the attractive Moldarta case which houses the Unit. *Pin jacks and leads with prod terminals provide the only connections necessary to the apparatus being tested.*

Sustained Accuracy—These Westinghouse Portable Test Units have a new type of d'Arsonval movement which assures an accuracy that cannot be deranged even under the most severe service conditions.

B-5705A

APPLICATION

Ohmmeter Test Units are primarily for testing circuit resistance, continuity, and insulation. They are sufficiently accurate for resistor classification and leakage limit testing of condensers. Volt-ohmmeter Test Units provide, in addition, for the measurement of a-c. and d-c. voltages and currents. Volt-ohmmeters are the most useful tools for exploration and trouble shooting in complex circuits; such as radios, public speech amplifiers, signal systems, talking movie sets, control systems, etc.

For detailed information, ask for C. S. 43-141.

SINCE Ⓦ 1888

METERS INSTRUMENTS RELAYS

Westinghouse

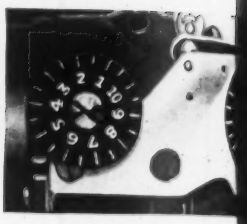
"TUNE IN" To Process Control

PROCESS LAG — CAPACITY LAG — THRUPUT CHANGES

. . . as Easily as dialing a Radio

Air-O-Line

Easily Adapted Then Fully Automatic



AUTOMATIC RESET

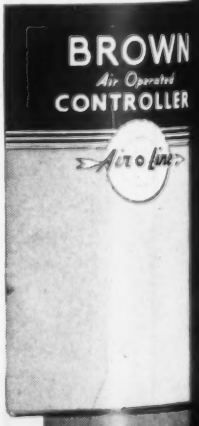
The graduated dial makes it possible to set the rate at which the control point is automatically set. No resistance coil is used.

THROTTLING RANGE

Graduated from ½ to 150 per cent throttling range. Sufficient flexibility to provide flexibility to meet any type of control problem.

Instantly adjustable without removing cover.

Other features are fully described in Catalog 8900. Write



The use of Graduated Dials for both "*Throttling Range and Automatic Reset*" in the Brown *AIR-o-LINE* is a revolutionary development in air operated controllers. They provide a means for "tuning in" to your specific process requirements, simply and quickly, without dismantling the controller or interrupting its control operation. Operators are encouraged to secure "best possible," not just "good enough," control results, so apt to be present where adjustments are complicated and time-consuming.

Brown *AIR-o-LINE* assures accurate measurement and precise control of temperatures, pressure, flow and liquid level—*AIR-o-LINE* is set with the same simplicity as dialing a radio—once it is "tuned in" it becomes fully automatic. Brown *AIR-o-LINE* not only confines the process within limits but it "lines out" control at the exact desired control point, regardless of load or thruput changes.

Brown *AIR-o-LINE* has everything you have wished for in air operated control—it "Recognizes," "Analyzes" and "Corrects" for any departure from the exact control setting—without "Cycling," "Drifting" or shifting of the control point.

Modernize your process control with this MODERN air operated instrument. Brown *AIR-o-LINE* is more than a controller—it's a system that will aid you to reduce costs—designed for outstanding performance with simplicity.

Learn more about Brown *AIR-o-LINE*—you can rely on its accuracy—be confident of its dependability. Write for Catalog No. 8900. BROWN INSTRUMENTS, a division of Minneapolis-Honeywell Regulator Co., 4482 Wayne Avenue, Philadelphia. Offices in all principal cities. Canadian Factory, 117 Peter Street, Toronto, Canada.

BROWN AIR OPERATED CONTROLLERS

OUTSTANDING PERFORMANCE WITH SIMPLICITY

A Heritage of Quality

WESTON *Instruments*

in all sizes, shapes, and for all requirements. The coupon will bring you full data . . . Weston Electrical Instrument Corporation, 582 Frelinghuysen Avenue, Newark, N. J.

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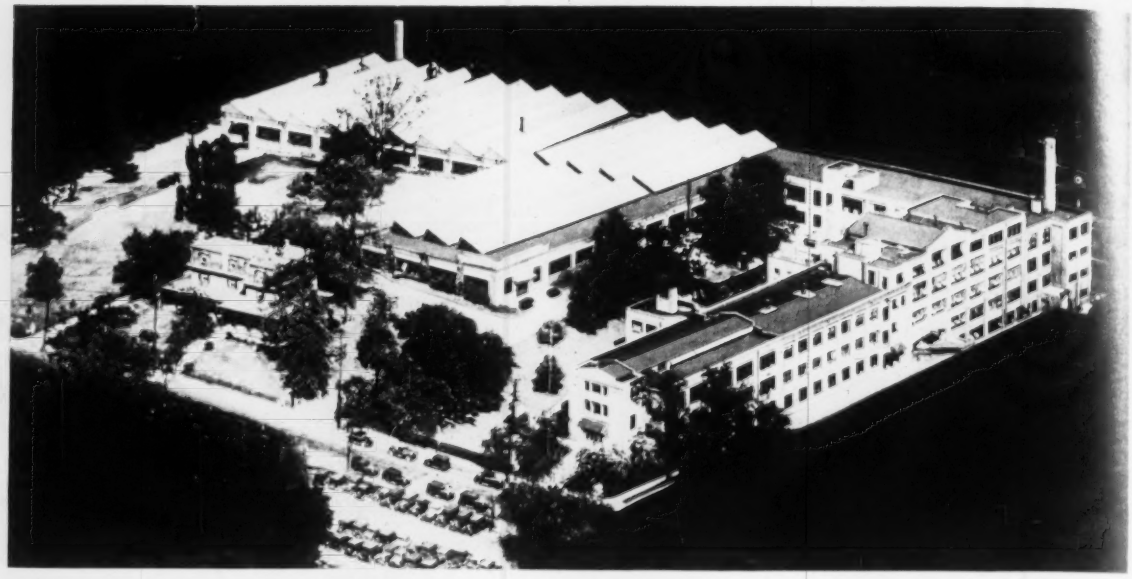

To You Who Read "Instruments"

May We Say . . .

That we hope to merit each month your interest in this page . . . on which we shall try either to tell of a time-tested measuring principle reduced to practice, of the merit of a particular instrument construction, of the value of some specific application, or merely to remind you of one or more members of our prolific family of instruments for research, teaching and testing, for power plant operation and for industrial measurement and control.

As a possible aid to appraisal of basic values, may we remind you that the automatic instruments which we offer in convenient, robust, plant models employ principles, circuit designs and fundamental elements such as galvanometers, resistors, capacitors and inductors which we have perfected during a third of a century of skilled and persistent development and have proved thoroughly in a wide variety of research, teaching and testing instruments ranging up to and including those of highest known precision.

We shall continue to endeavor to justify your confidence that Leeds & Northrup statements are as near to truth as we know how to make them.

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MEASURING INSTRUMENTS, TELEMETERS, AUTOMATIC CONTROLS
HEAT-TREATING FURNACES

EDITORIAL COMMENT

In This Issue

Ascription: It was the Minneapolis-Honeywell Regulator Co. which developed and built all the automatic pump control devices so interestingly described by Howard R. Green in this month's leading article.

Prediction: Anent the great advance in time-study methods reported by Professor Ford, a quotation from our August editorial may not be amiss:

In our opinion this [the work of Ford, Popplecretter *et al*] is only a beginning. The time-study man of the future will have been *trained* to operate *twenty-pen* or *hundred-pen* instruments producing analytical records of *all* that he sees when observing a task. Such records will constitute better "man-and-machine" process charts than are now made so laboriously without adequate Instrumentation.

Clarification: John L. Hodgson dispels uncertainties related to Reynolds Numbers.

Conjunction: The last system described in this month's instalment of our electrical instrument serial was patented Nov. 26—a few days ago—and the news came to us out of a clear sky in the nick o'time to make this issue. That's the ninth or tenth time a supernatural agency has made events happen just in time for our schedule of chapters!

Insulation: From two Belgian authors, through the courtesy of H. T. Kohlhaas of "Tel & Tel," came the article on chemical and electrical tests of insulating textiles.

Illumination: R. R. Batcher reports this month what is known on how best to make visible the cathode-ray "spot." He, by the way, is one of the workers in this very field.

The Counter Reads 9600

With this issue *Instruments* ends its eighth year. We thank those who have made us not only survive but grow; and extend to all our heartfelt good wishes.

Automaticity Makes Jobs

DESPITE the factual expositions of engineers, industrialists and economists who *know* the wealth-creating and wealth-distributing consequences of adopting cost-cutting devices, the anti-science, anti-machine, anti-progress agitation goes on and on.

It is becoming plainer that more than one selfish agitator is inflaming the rabble against labor-saving devices (and against private ownership thereof) in an attempt to become a dictator. Curious to know our enemies' tactics, we have listened to their broadcasts and read their printed manifestos, and find that no matter what panacea they lead up to, their common theme is the old hokum about a handful of plutocrats owning eight-tenths of all the means of production—from farm lands, cattle ranches, forest and mines to all the various processing and fabricating industries; nine-tenths of the means of transportation; and seven-tenths of the agencies of distribution. *Therefore* the plutocrats adopt labor-saving machines and methods to create hordes of unemployed who scramble for scarcer jobs. *Therefore*: (1) turn over the Federal Reserve to a few hundred slick politicians elected by popular vote, or (2) give half our national income to the aged; or (3) grab all privately-owned land; or (4) steal the factories and railroads and chain stores from their legitimate owners.

Throughout these fulminations runs the thread of resentment against technological progress: the would-be Hitlers claim that *because* we have emerged from the covered-wagon age it has become possible for a few plutocrats to own nearly everything and *therefore* we must kill, jail or otherwise dispose of the plutocrats, abolish our form of government . . . and give supreme power to Mr. X or Doctor Y or Father Z—who of course would somehow "distribute the wealth." . . . Of course! . . . Somehow!

What the would-be dictators conceal is that "purchasing power" is not absolute but relative. Automatic devices bring *down* the cost of cars and radios and gas and oil and electric energy and processed foods and good clothes and modern houses, thereby enormously widening the markets and creating millions of *new* jobs. These jobs are in "privately-owned" establishments. What of it? Under communism or fascism there would be even fewer overlords, exercising a far more despotic power without the possibility of tripartite governmental regulation.

For proof that automaticity makes jobs by making possible mass production, look at the automobile industry: look at it as a whole; or look at Buick, Nash, *et al*, which have recently modernized, slashed prices, widened markets and taken on thousands of new men.

M. F. BEHAR

Automatic Control of Pumps

By HOWARD R. GREEN
Howard R. Green Co., Consulting Engineers, Cedar Rapids, Iowa

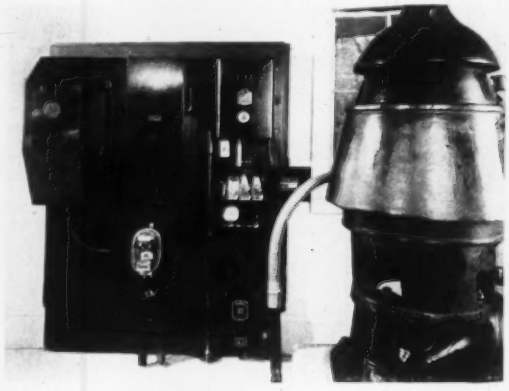
ALL life depends for its existence on adequate water supply. Municipalities and industries by the thousands are served by electrically-operated pumping plants. Persistent demand for reduced pump operating costs has resulted in development of highly efficient pumping equipment, and since municipal and industrial officials recognize that one of the major considerations is operating cost, they purchase equipment on the basis of efficiency.

Since pumping equipment must be installed for maximum demand and additional capacity allowance is generally made for future increase in demand, the equipment is usually operated at efficiencies much below maximum. This defeats the object which was expected when a premium for high efficiency was paid.

Where a customary elevated tank is employed as part of the system, the pumps are operated to maintain a predetermined level in the tank, within relatively narrow limits.

METHODS OF PUMP OPERATION

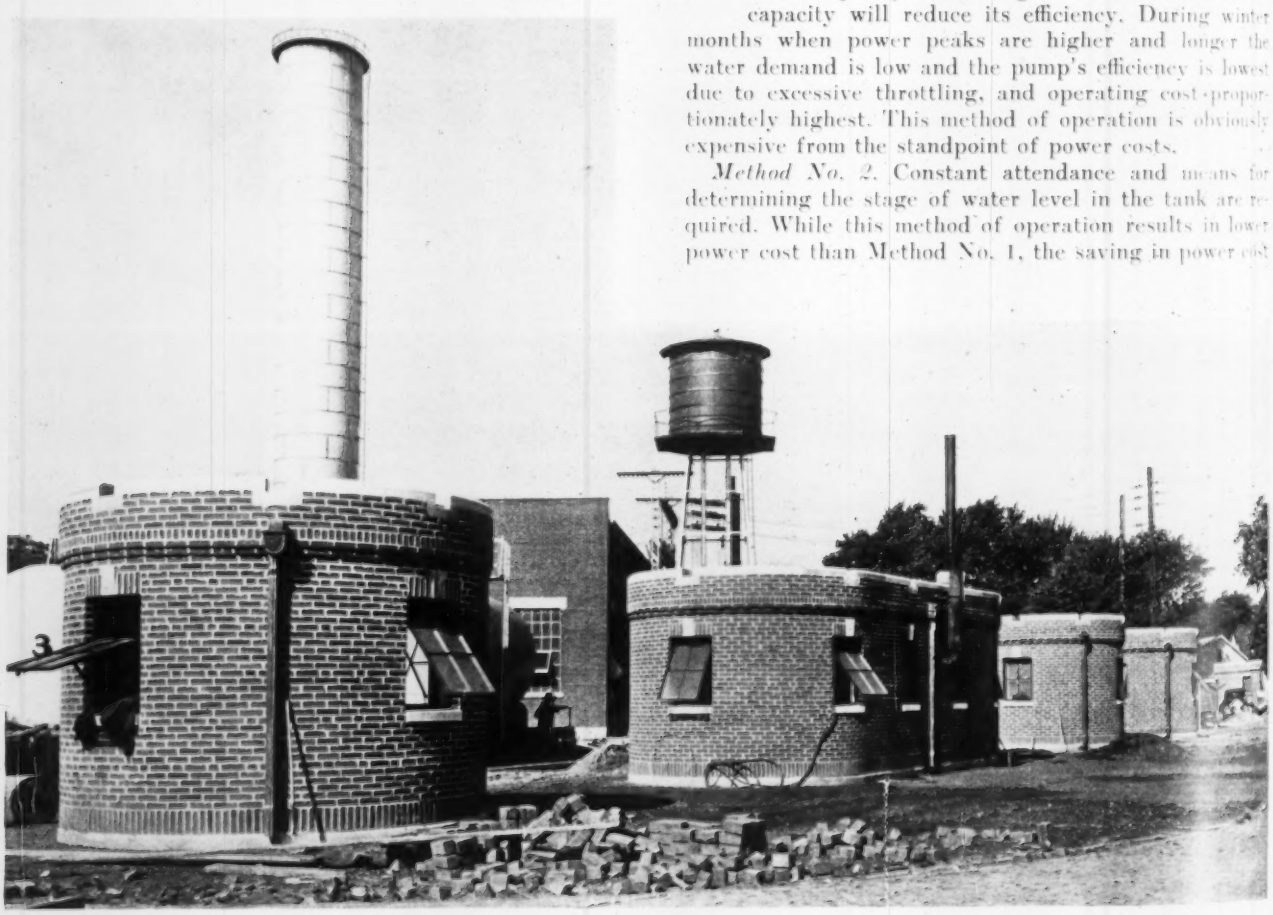
In general, three methods of operation are used: (1) Operating the pumps continuously but throttled down to prevent overflowing the tank during low consumption periods. (2) Where method No. 1 proves inadequate due to large fluctuations in demand, the pumps are operated to take care of the large demands and pumping rate is reduced when tank threatens to overflow. Such reduction in capacity is made by manually throttling the pump discharge or manually shutting down the system. (3) Automatic operation where the pumps are shut down automatically when a given maximum tank level is reached and automatically started at a given low level.



Above. One of six control panels and a centrifugal pump at Goshen, Ind., Waterworks. *Below.* General view of the Waterworks.

Method No. 1 can be used only where the demand is relatively constant. The pumps being adequate to take care of excessive demands must therefore be throttled during normal operation. Since the pump is designed to give maximum efficiency at its rated capacity, throttling it so as to reduce its capacity will reduce its efficiency. During winter months when power peaks are higher and longer the water demand is low and the pump's efficiency is lowest due to excessive throttling, and operating cost proportionately highest. This method of operation is obviously expensive from the standpoint of power costs.

Method No. 2. Constant attendance and means for determining the stage of water level in the tank are required. While this method of operation results in lower power cost than Method No. 1, the saving in power cost

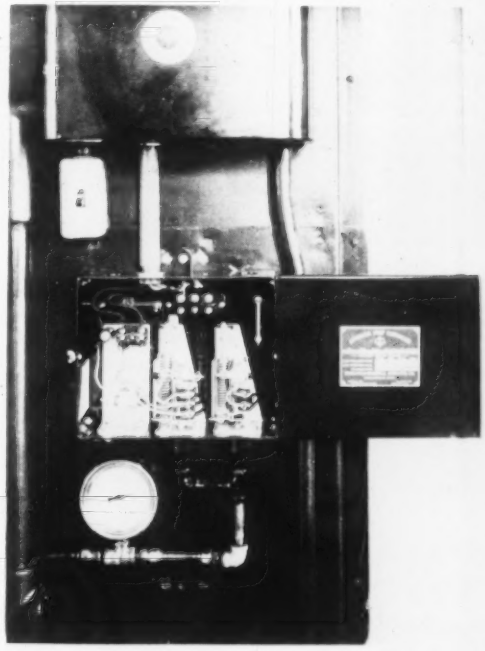


is offset by cost of attendance.

Method No. 3 makes it possible to utilize to the fullest extent the maximum pump efficiency, the pumps operating at full capacity and full efficiency. It should be apparent that this method is most desirable.

An automatic pump control operates to start the pump at a given low tank level and stop it at a given high level. In general two systems of automatic control have been used:

(1) *Float control system* where a float in the tank, rising and falling with changing water level, actuates an electrical contacting device which in turn operates the pump starter. Such a system can be used only where ice cannot form on the surface of the water. Since in most instances the tank is quite remote from the pump, there is involved a long run of wire between the two which in most instances is considered too expensive.



Close-up view of one of the control panels, whereby starting and stopping of pumps is controlled automatically as level in elevated tank varies.

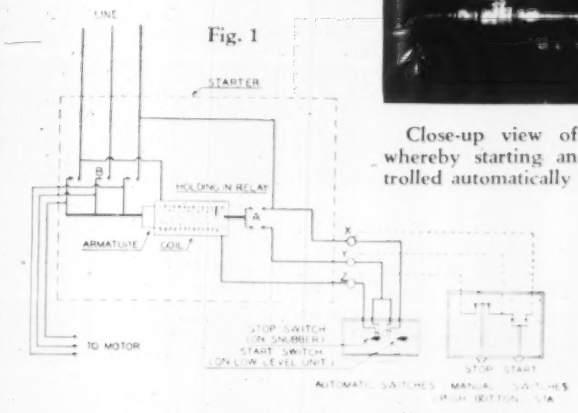


Fig. 1

(2) *Pressure Switch Control System* where a pressure actuated instrument is connected to the pump discharge at the pump house and is influenced by the changes in pressure due to changes in water level in the tank. This system has been proven to be most practical not only because of lower first cost but because the entire control system is located where it can be readily inspected and adjusted.

PRESSURE CONTROL SYSTEMS

The normal pressure at the pump discharge and therefore at the pressure controller is equal to the static head due to water level in the tank when the pump is not running; it is equal to the static head plus the pumping friction head when the pump is running. Therefore the pressure-actuated controller must be set for a cut-in (pump starting) point equal to the static pressure developed at the low water level in the tank; it must be set for a cut-out (pump stopping) point equal to the static pressure at the high level plus the pumping friction since the pump is running.

EFFECTS OF SURGES

When the pump starts it must suddenly set in motion a large mass of water which lies in the mains; when it stops this mass of water in motion suddenly stops. Surges are set up due to this sudden starting and stopping of the water. These surges result in excessively high pressures followed by excessively low pressures at the pump discharge and hence at the controller. These extreme high and low pressure points are far beyond the control settings.

Unless means be provided to eliminate the effect of surges on the controller, the pump will cut in and out with every swing in pressure due to surges. Altho the period of surge is ordinarily of only a few seconds' duration, if the pump were caused to cut in and out it might tend to prolong the surge period and it can readily be appreciated that this action would be detrimental to the pumping equipment.

Therefore to operate properly some means of eradicating the effect of surges on pressure control instruments must be provided.

ELIMINATING SURGE EFFECTS

A common method of eliminating surge effects on the pressure instrument consists of an air cushion tank connected to the pump discharge by a small pipe containing a needle valve. The pressure instrument is mounted in the tank and the needle valve is closed down so that a minute orifice exists. The rapid changes in pressures due to surges are not readily transmitted through the restricted orifice of the valve and the air cushion further retards the effect on the pressure controller. As long as the orifice does not become clogged and the air remains in the tank, this system gives fair

(Continued on page 347)

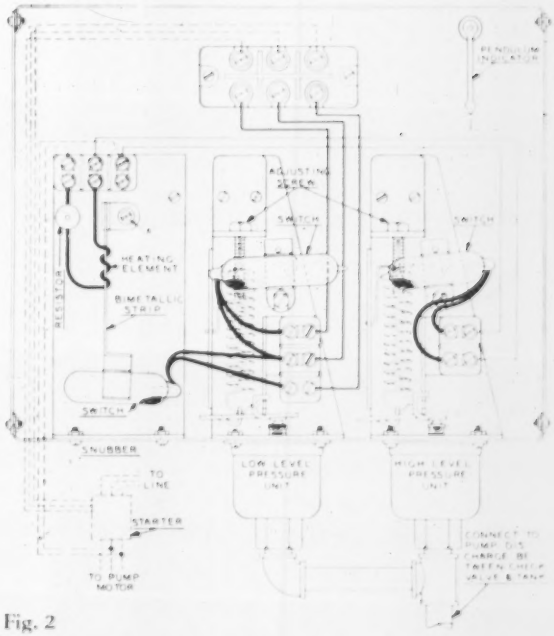


Fig. 2

A Direct-record Method of Time Study

By ADELBERT FORD
Professor of Psychology in Lehigh University

TIME STUDY MEN in manufacturing plants paying employees on a piece rate basis have customarily used stop watches or continuous hundredth-of a minute watches for determining the appropriate work rates before setting base wage scales. Usually one operation at a time can be recorded by these methods and the total picture of a job, usually known as a process chart, must be pieced together by combining the averages of many records. When a given work procedure will be used for a long time, and when piece-rate payment is skilfully used, per capita output of employees has frequently quadrupled day-rate performance, resulting in increased wages for employees and lower labor costs for the manufacturer. Such procedures must be so administered that the margin of savings will more than cover the cost of the time study man's activities. The editor of *Instruments*, in his August 1935 editorial, summarized the typical situation in the field of research on industrial time study:—

> We have cost-analyzed every occupation in the modern plant except that of the time study man himself, and he has gone on with but small regard for the overhead brought about by the use of instruments which were never designed originally for the task of motion analysis.

The several excellent suggestions advanced by the editor of this journal, and by such men as Poppelreuter, in Germany, have, for the most part, remained unused in the practical field. It is believed that the following account of the present project in plants of textile organizations will indicate some of the possibilities.

A silk garment factory in Eastern Pennsylvania found that changes in women's styles were so frequent that work analysis data became obsolete often in less than a week. It was decided to make time analyses of the individual items in a task, rather than in the completed commodity, as a basis for piece-rate determination. Sewing lace was cost analyzed by the yard, allowance being made for scallops and other irregularities. Costs were determined for sewing buttons, for threading elastic tape, for picoting edges, as individual work operations. When a new style of garment was received from the design department the total labor cost of that garment could be set merely by adding the standardized components of the task. This meant breaking up an occupation into shorter and smaller operations. Sometimes it meant timing the movements of the right and left hands separately. The times now became so short that stop watch notes were inaccurate. The well-known human reaction time errors became more serious.

To make motion pictures, analyze them for quantitative data, chart these data and apply the results in the form of standards—this solution would have been ideal in all respects but those of time and expense. The minimum delay would have been such that a job would sometimes be presented when the job had been discontinued; (2) the cost would have been scores of times too high even if the standards could be submitted immediately.

Other substitutes for the stop watch, which were commercially available and therefore given serious consideration, were various types of laboratory chronographs and of industrial strip-chart recorders. Investigation showed that all had distinct fields in which they rendered excellent service, but that none met the requirements of the situation as above outlined. There was required a new type of instrument applicable in particular to the garment industry and in general to all seasonal or other short-time factory occupations. This field is so large and diversified that it was decided to avoid scattering of effort and to perfect one design until it proved absolutely satisfactory in the Eastern Pennsylvania mills to which frequent visits were being made. The result, as often happens, seems to have a wide applicability. It is the combination of (1) a new technique of time study and (2) a new type of time recording instrument.

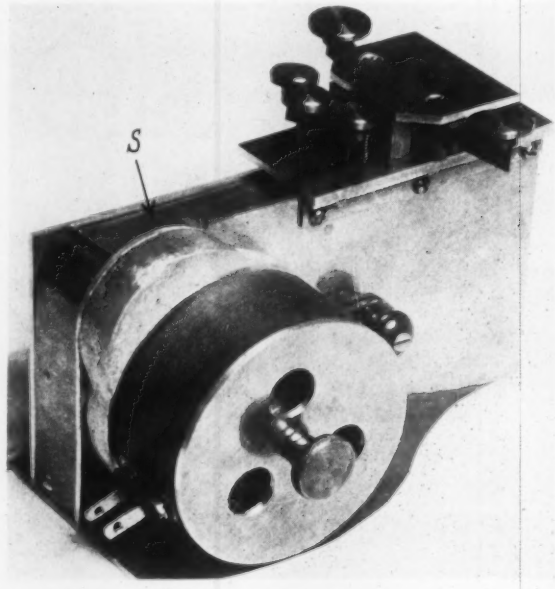


Fig. 1. A recent model of the Ascholiagraph.

The distinctive feature of the new technique is that the time-study man, instead of timing as usual only one item of an occupation (or two, if he can really *use* two stop watches at once) times a plurality of items simultaneously—up to five.

The distinctive feature of the new instrument is an arrangement of five keys or push-buttons which fits the pattern of the finger-tips of the normal adult's right hand.

The Ascholiagraph (from Greek roots, "picture of an occupation") is essentially a manually-operated tape chart recorder. See Fig. 1. Each of the five keys, when depressed, brings a stylus point against a moving strip of stylographic ("wax-coated") paper and makes a dark line whose length is proportional to the time the key is depressed. In using the instrument the time study man codes each finger with some phase of the task being studied. For instance, the thumb may stand for "materials layout"; the second finger may stand for "pickup"; the third finger may stand for "stitching"; the fourth may be depressed during the operation of "turning a scallop point"; and there still remains a key for "removal and stacking." When no key at all is depressed we have "waste time." This makes six items, which the psychologist knows is the limit of the normal attention

span without heavy amounts of automatization (mechanical half-t formation). Each key is held down for the duration of the period of the work item specified. Any time study man will now recognize that a ready-made process chart" is rolling forth from the keys.

Several ascholiagraphs have been built. From the very beginning of their development they embodied the five-key finger-fitting idea which makes possible a new instrumental technique of time study. Without light weight and small dimensions, however, a new type of industrial motion study instrument would find few logical applications. The earlier models were designed and constructed somewhat on the lines of conventional chronographs or of switchboard type multi-pen strip-chart recorders. The *results* obtained with them were altogether satisfactory but the writer, realizing that they were still *relatively* heavy and bulky, declined the invitations repeatedly extended by the editor of *Instruments* to disclose his work. The latest model, Fig. 1, is believed to approach the practicable ideal so closely that its announcement is no longer premature; its overall length is 8" and it weighs 5 lbs.

In the base of the instrument is a 300-ft. roll of 1" wide stylographic paper which is threaded under the five stylus points, and then passed between two rubber rollers on to the take-up drum. The paper passes over a visible stage (*S*) where it is possible for the operator to write notes concerning unexpected events. The two rubber rollers are driven by a 110-volt synchronous motor whose speed is as constant as the frequency of the commercial a-c. supply. In starting, the motor must be spun by hand by means of the milled grip fastened to the end of the motor shaft. In the gear housing between the motor and the drive rollers is placed a special transmission and clutch system operated by means of a protruding lever and knob at the side of the instrument. The point of this lever can be set

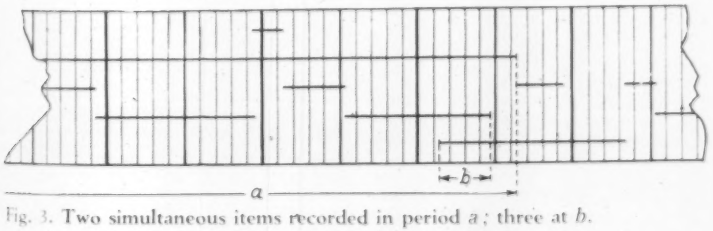


Fig. 3. **Two simultaneous items recorded in period *a*; three at *b*.**

at any one of three positions, "slow," "stop," or "fast," always without stopping the motor. When the lever is set at the "fast" position the tape is pulled under the writing points ten times as rapidly as when it is set at the "slow" position. When the lever is set at the latter position the 300-ft. tape roll will last ten hours, the tape speed being 0.1 in. sec. Obviously a roll will last one hour on the "fast" position, with a tape speed of 1 in. sec.

Up to a few weeks ago the only stylographic tape used was "blank," *i.e.*, without printed time graduations. Fig. 2 shows a portion of a typical record made in silk mills

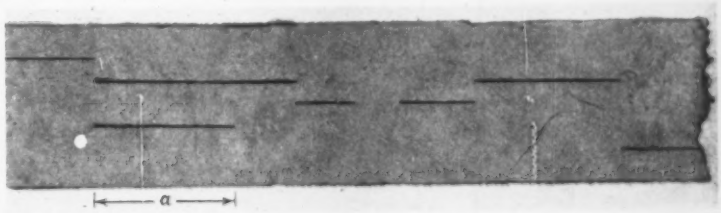


Fig. 2. **Note that two simultaneous items were recorded in period *a*.**

time study. Since the tape was traveling at constant speed when this record was made, it requires only the superposition of a transparent celluloid scale to read off the duration of any desired operation in the code. In our work we used a scale graduated in hundredths of a minute, in order to continue the standards which had been started on the basis of a watch with a minute dial thus graduated. The celluloid scale length for one minute (on a "slow tape" record) is 6" and this linear interval is divided into 100 graduations. A scale which reads in seconds is one on which each 6" interval has 60 equal divisions. Thus the type of record shown in Fig. 2 can be read either in hundredths of a minute or in seconds, depending on which transparent scale is used. If the tape was traveling at "fast" speed when the record was taken, the ultimate divisions of the two transparent scales then give direct readings in thousandths of a minute, or in tenths of a second, respectively.

Table I. Illustrating time standards secured by the use of the Ascholiagraph. Type of Occupation: Cutting cloth for women's undergarments. Equipment used: Rotary power cutting knife. Material: Rayon. Operator No. 12.

Shape of Cut	Length of Cut Inches	Number of Readings Taken	Time in Minutes per Operation		
			High	Low	Average
a-h	16	2	0.22	0.20	0.21
b-h	20	5	0.55	0.37	0.44
c-h	26	11	0.56	0.19	0.37
d-h	28	4	0.34	0.31	0.32
e-h	31	7	0.60	0.40	0.47
f-h	34	7	1.02	0.22	0.50
g-h	42½	3	0.40	0.33	0.36
h-h	51	1			0.26
i-h	53	8	0.65	0.49	0.58
j-h	55½	3	0.51	0.38	0.45
k-h	63½	8	0.59	0.38	0.42
l-h	68	10	0.57	0.35	0.47
m-h	75	4	0.46	0.27	0.38
n-h	76	10	0.63	0.52	0.58
o-h	81	19	0.73	0.38	0.48
p-h	84	15	0.60	0.45	0.56
q-h	86½	6	1.01	0.66	0.83
r-h	87	10	1.02	0.47	0.66
s-h	90	22	0.55	0.38	0.44
t-h	92½	7	0.60	0.40	0.46
u-h	93	22	0.91	0.47	0.72
v-h	94	22	0.85	0.44	0.64
w-h	94½	18	0.92	0.50	0.62
x-h	95½	13	0.55	0.42	0.47

In addition to "blank" tape, we are now using also printed tape, bearing time divisions as do the familiar strip charts of switchboard recorders. Fig. 3 shows a portion of a record taken on a tape printed in decimal graduations, representing tenths (heavy lines) and hundredths of a minute at "slow" speed, or hundredths and thousandths at "fast" speed. In factories where the hundredths of a minute system is standard, a record as shown partly in Fig. 3 constitutes a ready-to-use "process chart."

As soon as records are made, the time study man identifies each by writing on the tape the date, the operator's number, etc., including also (when he does not use the same code throughout his work) either the individual designations of the five timed items or, simply, one letter or number to designate the particular code used. The records or "process charts" are not ends in themselves but raw data from which comparisons are made, rates set,

(Continued on page 347)

The Reynolds Number

By JOHN L. HODGSON

Egginton House, nr. Leighton Buzzard, Beds., England

CONTAINING seven contributions to the art and science of fluid metering, the August 1935 issue of *Instruments* is of permanent reference value. For that reason, one of the oldest workers in the field (and one who is quoted by several contributors) deems it worth while to clear up several points in that issue.

The use of the Reynolds Number, *as applied to orifice and nozzle measurement*, did not originate with either Reynolds (page 198) or Stanton (page 203, footnote 1). I had been first intrigued in its possibilities by a paper by Bairstow on the laws of similitude. This paper was published in the July number of *The Aeronautical Journal* for 1913. I had, since 1909, been trying to correlate the coefficients of various possible flow metering devices (including nozzles, orifices and "gate" meters) for air, gas, steam and water flows. As stated in the closure of my 1917 paper[1] on "The Commercial Metering of Air, Gas & Steam," I had not, up to that date, found the Reynolds Criterion of much practical use, as the commercial demands in which I was then interested were for higher velocities than those for which the criterion applied. In that closure, I gave a more general criterion, which included both elastic and viscous flows, and of which relation (8), quoted on page 201 of the August *Instruments* by Ed S. Smith, Jr., is a particular case. This general criterion is further discussed in appendices IV and V of my 1925 paper[2] on "The Orifice as a Basis of Flow Measurement," and in appendices (4) and (5) of my 1929 paper[3] on "The Measurement of the Flow of Gases and Liquids by means of Orifices, Nozzles and Venturi Tubes."

Figs. 32, 33, and 35 of my 1917 closure show the results of the first tests ever made to apply what is now called the Reynolds Number to orifice flows. These had been carried out as a result of Bairstow's paper, and of correspondence with the late Lord Rayleigh. They clearly show the upper limitations of the criterion when applied to gaseous flows, as well as its great value when applied to lower velocities than were then of commercial interest.

It would seem preferable to plot the Reynolds Criterion in terms of D_2 and not of D_1, as this simplifies the use of the curves. (This has also other advantages, see my footnote No. 4.)

The expression vd/ν (adopted by the German investigators when repeating my original work) is, as a kinematic viscosity, is a form of the criterion introduced by the late Lord Rayleigh in connection with his mathematical work. When considering problems of fluid measurement the essential factors are size, D; density, W; viscosity, μ; velocity, V; weight flow, G; volume flow, Q. There is no point in introducing the concept of kinematical viscosity in connection with fluid metering problems.

The most fundamental form of the criterion is therefore $\frac{VDW}{\mu}$. But as this involves statement of whether it is V_1 or V_2 that is measured, and as flows are usually stated in gallons or pounds per second—and not in velocities, more convenient forms of the criterion are $\frac{QW}{D\mu}$ or $\frac{G}{D\mu}$. The form of the criterion which I myself have found most generally useful when dealing with flow measurement within the viscous range is $\sqrt{\frac{G}{D_2\mu}}$.

R. B. Smith's contribution on page 204 is most important. Orifices must be made of ample stiffness. Thin orifices are apt to vibrate as well as to distort under differential pressure. The coefficients of vibrating orifices over their range of resonance make such orifices quite useless as flow measuring devices. The flow through them may actually be lower at the higher heads!

Ed S. Smith, Jr.'s valiant attempt to cover with a formula coefficient curves such as I first published in my 1925 paper is of academic value only. It was apparent as soon as those curves were obtained that some form of obstruction which had characteristics intermediate between those of a square edged orifice and a rounded nozzle should have a constant coefficient down to fairly low values of $G/D_2\mu$. Such an obstruction was therefore worked out with the results given in Fig. 1.[4] It will be seen that for orifices of large diameter ratio, the extension of the flow range of the constant coefficient is about 3 times; while for orifices of small diameter ratio—which most frequently occur in practice—the extension of the flow range is *more than 100 times*. In modern practice one would therefore never think of using a square-edged orifice with its heavy viscosity correction at low flows, for the measurement of viscous oils.

[1] *Proceedings* of the Institution of Civil Engineers (London), Vol. 204, Part 2, 1917, pages 104-293. (Actual reference, pages 186-191.)
[2] Institution of Civil Engineers (London), *Selected Engineering Papers*, 1925, No. 31, 23 pages. (Actual reference, pages 18-21.)
[3] *Proceedings of World Engineering Congress*, Tokio, 1929, *Engineering Science*, Part 2, pages 97-150. (Actual reference, pages 131-134.)

[4] It will be noted as a point of interest that it has not been possible to obtain a constant coefficient at values of the criterion which lie below the limiting curve *ABC*. (Incidentally, this is an effect which would not have been apparent if the criterion had been plotted on a D_1 basis.)
[5] It does not seem necessary to elaborate the fact that since the viscosity of an oil changes rapidly with temperature, the values assumed for the orifice coefficient at various rates of flow (unless these do not deviate appreciably from some constant value) can only apply to an oil of constant composition and quality at constant temperature.

Widely known as an eminent pioneer in fluid metering and automatic control, John L. Hodgson invariably sheds interesting light on the topic under discussion. In the present instance he relates the circumstances leading up to the first use of the Reynolds Number in connection with orifice and nozzle flows, discusses other matters treated in our August 1935 issue, and arouses our burning curiosity by disclosing the coefficients of an "intermediate" differential producer (which seems to be both an orifice and a nozzle without being either!)—M. F. B.

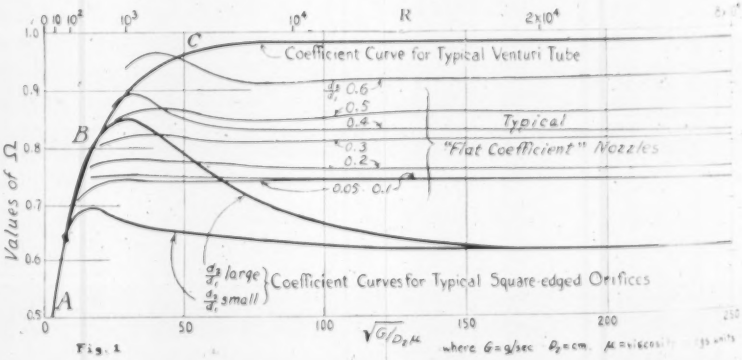


Fig. 1

Telemetering and Totalizing*

By PERRY A. BORDEN and M. F. BEHAR
Member A.I.E.E. Editor, *Instruments*

Continued

8. Position Class

(a) Definition

It may not be amiss to start by dispelling the confusion created by the flexible meaning of "position." This can best be done by first eliminating the inapplicable meanings.

(1) Systems belonging to any of the five classes (current, voltage, frequency, position, impulse) are used in practice for telemetering the positions of floats, pointers, valve stems, etc. Any system, when so used, becomes a position telemetering system. (In like manner one speaks of a pressure telemeter, a flow remote-recorder, a load totalizer, etc.) This is one sense—that of "duplicated position"—in which the term "position" cannot be used to define one of the five classes to the exclusion of the other four.

(2) The basic principle of any telemetering system may be said to involve transmitting the position of a measuring pointer. Any system, viewed in this light, is a position system. This is the *general* "duplicated position" meaning obviously too general to define one class.

The five-class scheme is based on the various electrical transmitting principles actually employed—not on what is measured nor on how it is measured, but on what is transmitted: i.e., on the electrical effect into which the result of the primary measurement is converted in the transmitting section. The term "position," then, refers to the transmitted electrical magnitude which represents the value of whatever magnitude is measured. It refers to electrical ratios, electrical phase angles, etc. Thus, there naturally exists a distinct electrical position class of systems: it would exist on paper even if not a single bridge or ratio or induction-balance system had been brought out commercially.

Ideally, the position class would include only such systems. Since, however, all telemetering systems use some sort of "duplicated-position" idea, any new system using a transmitting principle which is not that of current, voltage, frequency or impulse may be assigned to the position class. This has been done for years. The result is that the position class is a heterogeneous grouping of different types.

(b) Principal Types

There are four distinct types and one rather broad type of position systems—which five it is well to consider as divisible into three groups:

(I) Those using transmitting principles involving purely electrical position effects. This group contains the first two types:

Type 1—Ratio
Type 2—Bridge

(II) Systems in which the transmissible electrical position effect is inseparably associated with the spatial relations of essential mechanical elements—mechanical similarity of transmitter and receiver being indispensible.

Type 3—Induction-balance
Type 4—Position-motor

(III) Miscellaneous systems which depend for their operation upon the shapes and arrangements of mechanical members and which do not depend definitely upon the use of electrical position principles. In the present state of the art we may refer to all systems in this group as Type 5.

The operating principles of the five types are, in brief, as follows:

(1) *Ratio Type.* By means of an adjustable potentiometer-type rheostat, or more commonly by inductive means, there are established in the transmitting circuit two voltages or currents having relative values governed by the primary

*Sixteenth chapter (XLIV) of Part Seven (Handbook of Industrial Electrical Measurements and Control) of Behar's *Manual of Instrumentation*. See editorial announcement of this series on page A7 of November 1933 *Instruments*. Each chapter is subjected to a final revision shortly before its appearance in this serial form, in order to assure that the subject matter is thoroughly up-to-date. This new book is not published serially in any other periodical. Entire contents copyright.

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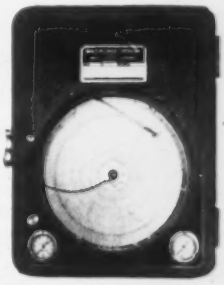
Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

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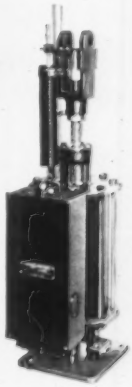
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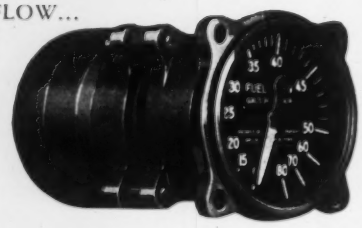

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measuring element. The receiving instrument takes the form of [illegible] such as may be developed from a crossed-coil movement or its equ[illegible]

(2) *Bridge Type.* A self-balancing instrument at the receiving [illegible] restore the balance of a bridge circuit unbalanced at the transmi[illegible] the primary measuring element.

(3) *Induction-balance Type.* The relative value of two induc[illegible] a-c. circuit is varied by the primary measuring element, thus unba[illegible] electromagnetic stresses on opposed elements at the receiving end. T[illegible] element automatically tends to restore the balance, maintaining a [illegible] determined relationship between the inductances in the two bran[illegible] circuit.

(4) *Position-motor Type.* Two or more secondary circuits havin[illegible] relationship with a common primary circuit are simultaneously var[illegible] their relative mutual inductances change. The voltages induced in th[illegible] under a-c. excitation are applied to a similar arrangement in the re[illegible] tion, causing the moving element thereof to duplicate the position [illegible] the transmitter.

(5) *Miscellaneous.* No distinct principle common to all Type [illegible] Only in one respect can all be said to come under this heading: no[illegible] elsewhere.

(c) Features and Characteristics

By reason of the diversity of their types, position systems have few common features and characteristics. There are exceptions to each of the following statements:

In general, position systems require three or more conductors in the interconnecting circuit; and this has a tendency to restrict distances over which they may economically be used, as well as to limit the practicability of utilizing the standard types of communication circuits.

Even when one conductor is replaced by "ground," the line wires are seldom in a condition of balance which lends itself to incorporation into circuits used for other purposes.

As an offset against the circuit limitations, the position systems are generally characterized by the advantages of quick response, high torque and precision of indication.

Where the transmitted effect takes the nature of the ratio between two similar electrical magnitures, and where ratios between linear quantities determine the indication of the receiving instrument, the transmitted current or voltage may be either direct or alternating; but where phase angles are involved it is obvious that a-c. magnitudes only may be considered.

Position systems may be used for telemetering all kinds of measurements—flows, temperatures, watts, amperes, volts, water levels, etc., and (of course) positions of valves, dampers, etc.—all depending on the primary measuring element in the transmitting section.

It is in this class, particularly, that there are found relatively large and powerful systems capable of operating various devices at the receiving end. Such systems represent the transition from telemetering to remote control.

(d) Type 1—Ratio Systems

In the simplest of the ratio systems the principle of the crossed-coil movement (*Instruments*, March 1934, pages 54-55) is extended to the expression of a ratio between two currents or voltages simultaneously regulated by influences of the primary measuring element. This regulation may be effected either by a rheostat, as in Fig. 44-27 or (when alternating current is used) by a variable inductance, as in Fig. 44-28. Both these methods are subject to the limitation of requiring an appreciable amount of power to perform the adjustment in the rheostat method because of the element of friction essential to satisfactory

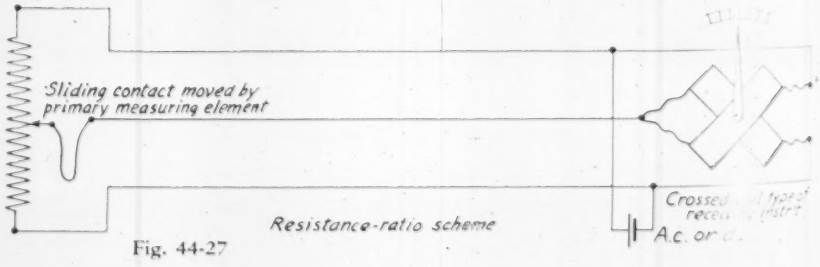
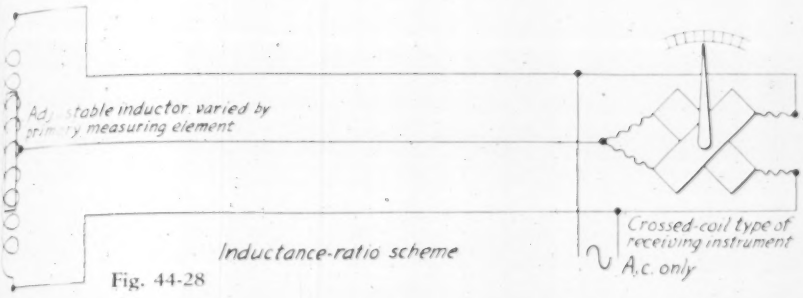


Fig. 44-27



Inductance-ratio scheme

Fig. 44-28

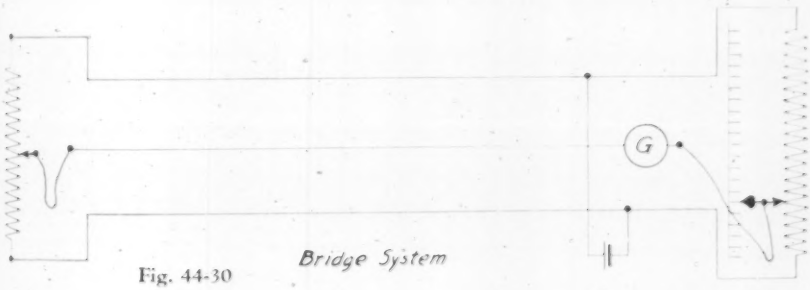
performance, and the inductive method because of electromagnetic reactions set up in the inductor by current flowing in the line. The primary measuring element must therefore be of such type and construction that it can operate the mechanism without serious loss of sensitivity or accuracy.

A representative commercial example of the use of the ratio principle is the "Teldicator" line of instruments, produced by the Meyer Instrument Co. for the remote indication and recording of flow rates, liquid levels, positions, etc., the transmitter taking the form of a soft iron plunger moving in a double solenoid coil in response to variations in the magnitude being measured. This coil is connected by three wires to a dynamometer-type receiving instrument which measures the ratio of coil voltages as determined by their respective inductances, thus providing an indication of the position of the plunger in the transmitting section.

The ratio type of telemeter has found wide application in helm indicators for ships and position indicators for tap-changing transformers, as well as in providing remote indications of the readings of relay-type recorders. Considerable research has been done on systems in which the ratio of two magnitudes is represented by the relative value of two electric currents or voltages of different natures, as alternating and direct current or alternating currents of different frequencies, which may be superimposed in a single two-conductor circuit at the transmitting end and separated by a filter at the receiving end. The work of Midworth in England represents probably the most complete study of the possibilities of this general method of which published records are available *

(c) Type 2—Bridge Systems

In the bridge system (Fig. 44-30) as in the ratio system, there is required at the transmitting end an adjustable resistor, the receiver taking the form of a self-balancing instrument acting in response to a relay mechanism to reduce to zero the current flowing in the middle wire, thus restoring the balance of a



Bridge System

Fig. 44-30

circuit which is the equivalent of a Wheatstone bridge. (See *Instruments*, Nov. 1934, page 229.) A representative commercial example of this type of system is that of the Bailey Meter Co., Figs. 44-31 and -32, which employs a "Galvatron" self-balancing recorder (see *Instruments*, Feb. 1935, page 34) in the receiving section.

The adaptability of the bridge principle to the use of standard equipment developed for other purposes has led to its adoption in many instances of telemetering systems for the remote indication of gate openings, rheostat settings, water-level recorders, etc., developed by the users in their own shops.

This method is frequently used also for re-transmitting the readings of a recording potentiometer. The bridge system here uses practically the same equipment as would be required for a voltage system, with the electrical dif-

*British Patent No. 400,289, C. Midworth, Oct. 26, 1933.

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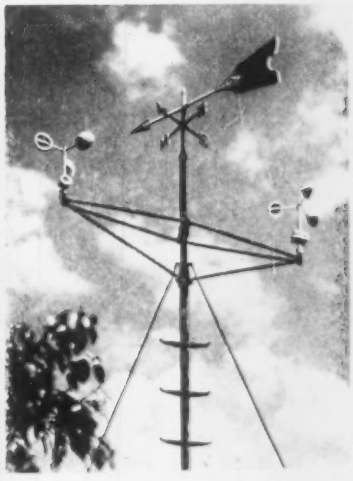

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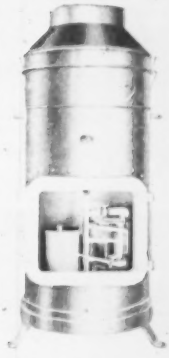

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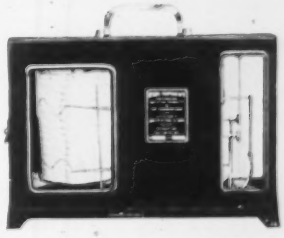

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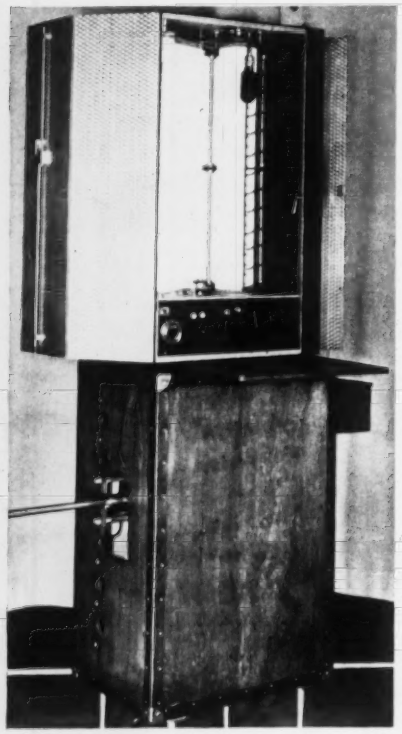

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ference that, with the use of a bridge circuit having three conductors, the receiving instrument takes the nature of a bridge rather than a potentiometer and thus eliminates the need for a standard cell with its attendant requirement of periodical adjustment of the slide-wire current.

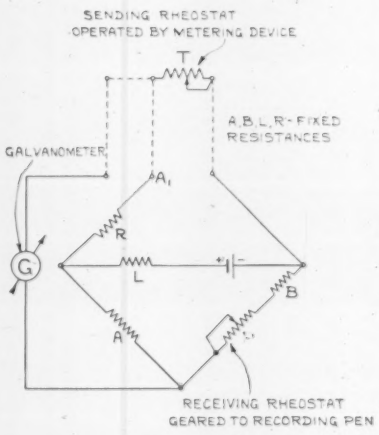

Fig. 44-31

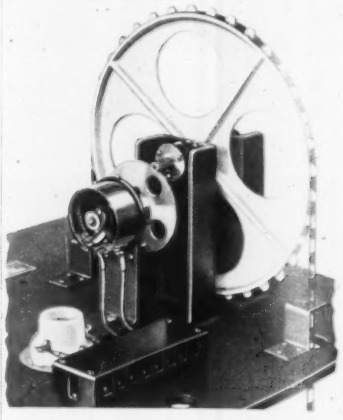

Fig. 44-32

(f) Type 3—Induction-balance Systems

The transmitter of the induction balance system takes the form of a pair of variable inductances mechanically interconnected and varied with the value of the measured magnitude. The electrical circuits are such that the variation of inductances tends to vary the relative value of voltages in two sides of a three-conductor system. The receiver resembles the transmitter and is so arranged that the two inductances in it tend to adjust their position to one in which the relative value of their associated voltages is the same as that of the transmitters, with the result that the line current is reduced to zero, or to a value where the reaction of the transmitting element on the primary measuring element is minimal. Thus, one advantage claimed for the principle lies in the fact that, though during changes in the reading the primary element may be subjected to electromagnetic forces from the transmitter, these forces neutralize when equilibrium is finally attained, and leave no reaction to interfere with the measuring unit taking up its true position.

One of the earliest and best known systems using the induction balance principle is the long-distance system introduced about 1912 by the Bristol Co. Two coils carried on a rigid structure and balanced on knife-edges constitute each basic unit (see Fig. 44-33). With each coil is associated an open iron

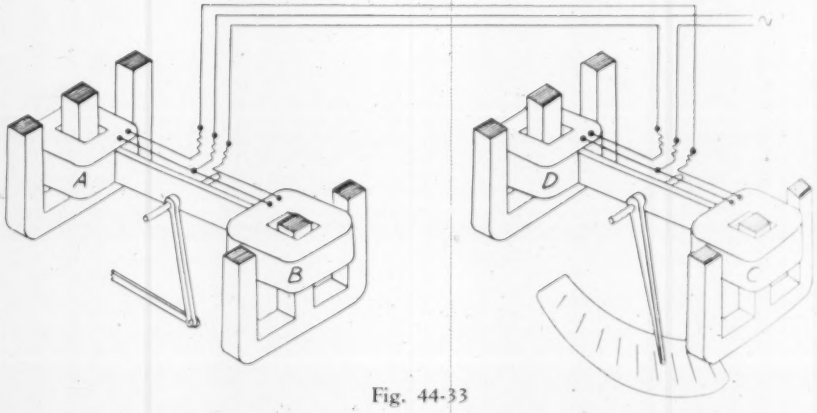

Fig. 44-33

magnetic circuit, so placed that as one coil moves to encircle more of the iron the other moves to encircle less, and the inductance of one coil increases as that of the other decreases. This arrangement is duplicated in the transmitting and receiving instruments, and electrical connections are made as indicated in Fig. 44-33. Alternating current introduced into the common wire will divide in inverse proportion to the impedances of the respective branches of the circuit. Thus, with the coils of the transmitting unit in the positions shown, coil *A* will have a higher inductance than coil *B*, with a consequent tendency for the latter to carry the greater proportion of the current flowing. Coils *A* and *B* in

the transmitter being connected in series with coils C and D respectively in the receiver, the electromagnetic pull set up by coil D acting upon its iron core will overcome that set up by coil C, and the moving structure will swing in response to the difference in pull of the two coils. At the same time, as coil D moves into a position to embrace more of the stationary iron core, its inductance will automatically be increased, with a consequent reduction in the current flowing, while for the same reason the current in the weaker coil will be increased. There is thus established a self-balancing action in which the system tends to come to equilibrium with equal total values of impedance in the two branches of the circuit, and hence with the moving elements of the units in corresponding positions, under which condition the reaction of the coils on the primary measuring unit in the transmitter becomes nil.* Fig. 44-34 shows the induction balance type of receiving element incorporated in a Bristol round-chart recorder.

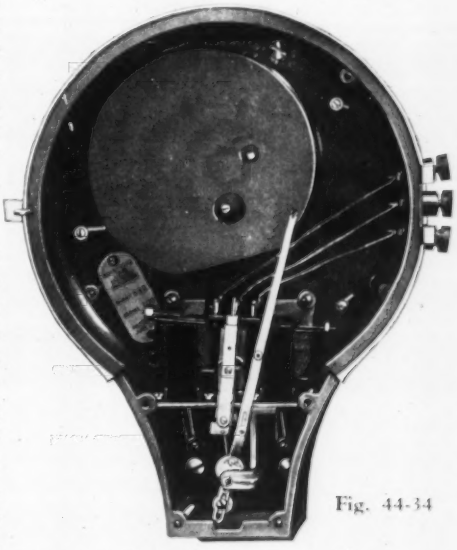

Fig. 44-34

In the induction balance system of the Brown Instrument Co. the operating principle is electrically identical with that described above, but the electrical

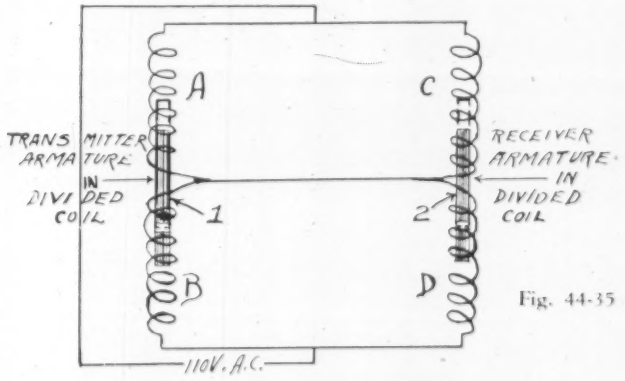

Fig. 44-35

circuits are stationary, taking the form of a divided solenoid, and the magnetic system consists in a plunger which moves on the axis of the coil, and varies the relative inductance of the two sections according to its axial position. A schematic diagram of the system is shown in Fig. 44-35. The electromagnetic reactions are such that the plunger in the receiving unit takes up a position

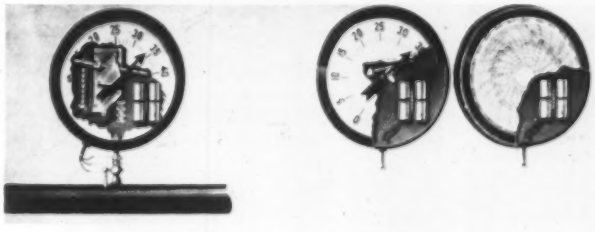

Fig. 44-36

representative of that in the transmitter, the condition of balance automatically reducing to zero the mechanical force exerted on the primary measuring unit. Fig. 44-36 shows a Brown remote installation having two receiving units, one recording and the other indicating the pressure in the pipe line at the left. For flow telemetering, the transmitting section is a Brown differential-pressure manometer.

In the "Electruflo" meter of Morey & Jones, Ltd., the principle of the induction balance has been combined with a relay system, so that the balance between transmitting and receiving elements is forcibly restored by a motor-

*U. S. Patent No. 1,028,851, J. W. Bard, June 11, 1912.

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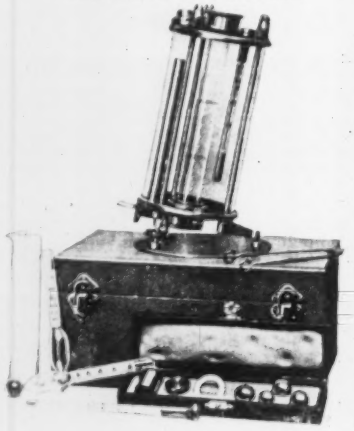

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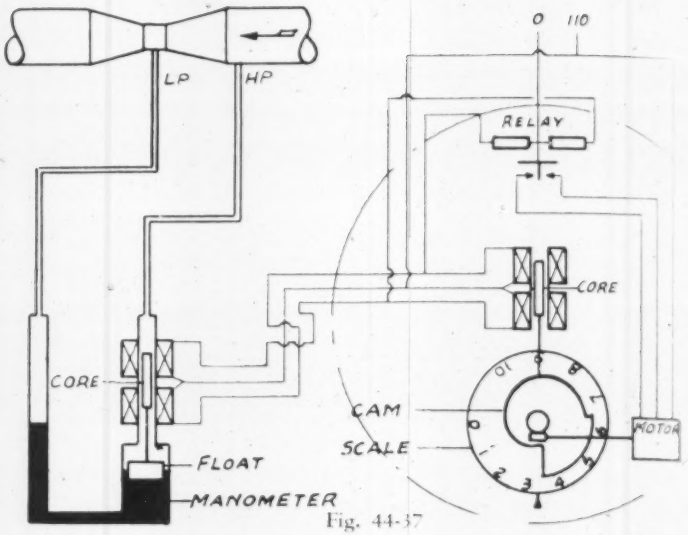
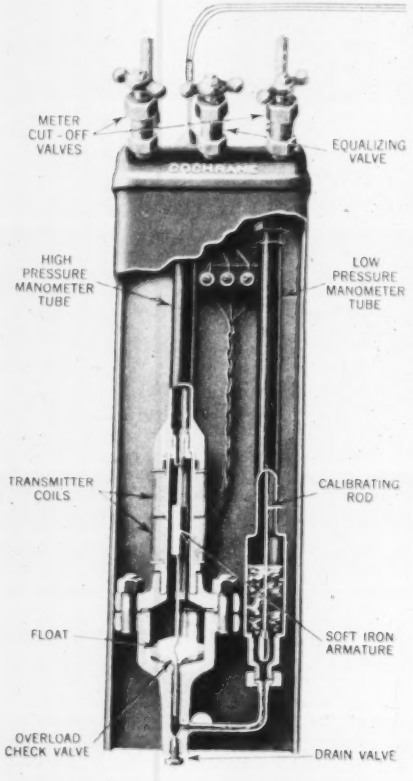


Fig. 44-37

driven cam acting upon the magnetic element of the receiver.* The cam motor is controlled by a relay energized from the lines and responding to any condition of unbalance set up by the transmitter. A diagram of the apparatus arranged as a flow meter is shown in Fig. 44-37. The ultimate reading is determined from a scale showing the position of the cam; and it will be apparent that, by suitably shaping the cam contour, it is possible to reduce to a straight line law the measurements derived from a primary element, such as a differential head type of flow meter, having a non-linear characteristic.

Fig. 44-38



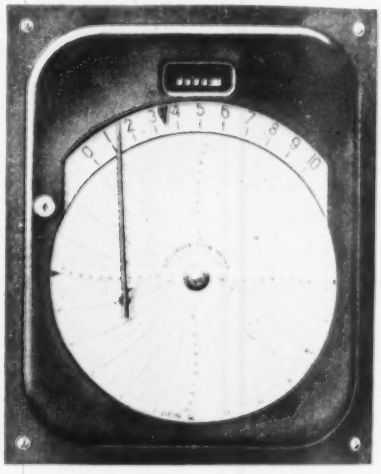
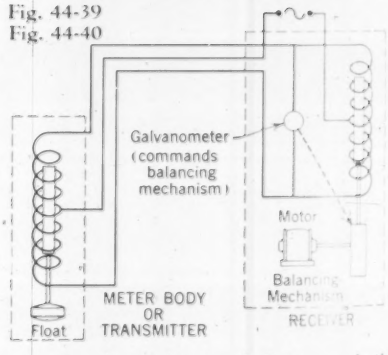


Fig. 44-39

Fig. 44-40



At this writing the latest flow meter employing the induction-balance method of telemetering is that of the Cochrane Corp., Figs. 44-38 to -40. In the receiving section the servo-motor (commanded by the galvanometer) moves the plunger of the divided solenoid through a cam so shaped that the squared relation between flow and pressure differential is rectified, permitting the servo-motor to be geared directly to the indicator pointer, recorder pen arm and integrator index.

*U. S. Patent No. 1,877,810, L. H. Chamberlain, Sept. 20, 1932.

(g) Type 4—Position-motor Systems

Position-motor systems (sometimes referred to as "self synchronizing") may be considered as an evolution of the induction balance system, developed in the form of a motor, generally free for complete rotation. The essential electrical distinction between the induction balance system and the position-motor system lies in the latter having a constantly maintained alternating magnetic field, requiring that both the transmitting and the receiving units be provided with excitation from a common a-c. source. Structurally, the two elements are generally identical with each other, each being substantially a wound-rotor induction motor having one single-phase and one polyphase winding, the former usually being on the rotor and the latter on the stator. The most common system of inter-connection is that shown in Fig. 44-41. It will be observed that the single-phase winding in each unit is excited from the a-c. line, while the polyphase windings are connected through the three-conductor transmitting

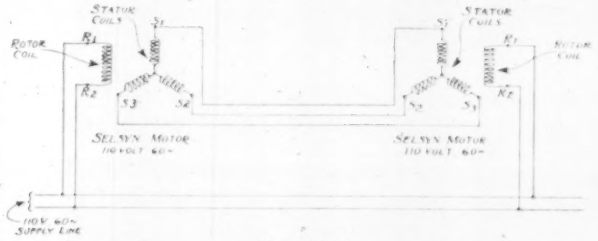


Fig. 44-41

circuit. The transmitting instrument may be considered as an induction regulator controlling the relative values of three voltages. It is to be noted that, while the secondary windings have the equivalent of a polyphase connection, *there are no polyphase-voltages in the system*, the three voltages in the interconnecting line being in phase with one another and having an algebraic sum of zero. The resultant action of the three voltages upon the receiving unit is to set up an alternating field having a position in space corresponding to that of the magnetic axis of the single-phase primary winding in the transmitter; and the single-phase element of the receiver tends to move into a position where its field coincides with that of the three-phase winding, thus providing at the receiving end a duplication of the position at the primary end. In this position the voltages set up in the receiving instrument exactly neutralize those set up in the transmitter, reducing the line current to zero and eliminating reactions on the primary measuring element.

Though the position motor is essentially a single-phase instrument, it is possible to operate it "inverted," by exciting the three-phase windings of the transmitter and receiver from a common polyphase source, and interconnecting the single-phase windings through the transmitting line. The transmitter then becomes a phase-shifting transformer, the transmitted magnitude a constant voltage of variable phase position, and the receiving unit the equivalent of a power factor meter. By providing a three-phase winding on both rotor and stator of

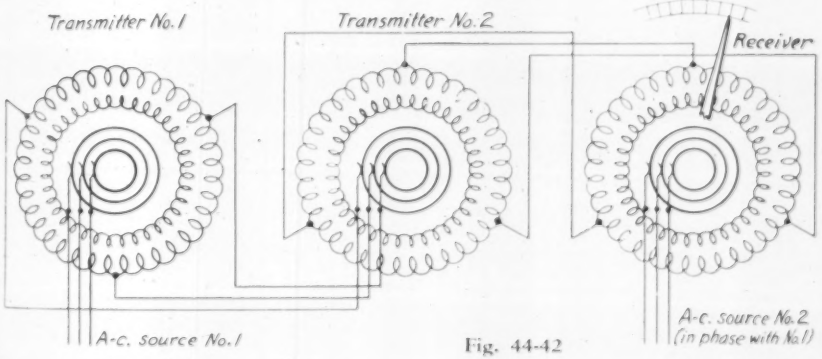


Fig. 44-42

each unit it becomes possible to accomplish totalization by the use of a concatenated or cascade connection, as shown in Fig. 44-42. As any possible advantage of this method of using the position motor is usually offset by the tendency of the rotors to rotate continuously under the influence of the polyphase field, it is used only in exceptional cases, and is here mentioned only as a matter of technical interest.*

*For other systems of totalizing with selsyn motors see U. S. Patents 1,732,987 and 1,895,942: R. M. Rowell.

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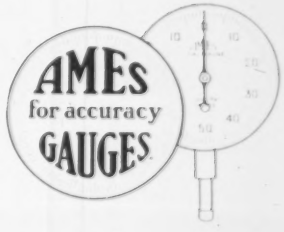

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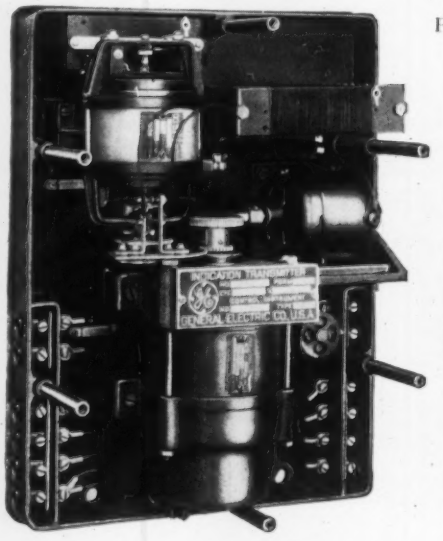

Fig. 44-43

Fig. 44-44

Position motors manufactured by the General Electric Co. under the trade name of "Selsyn" (self-synchronizing) are obtainable in a variety of models suited to position indicating as well as to some forms of remote control in the operation of valves and rheostates. Fig. 44-43 shows a typical G-E transmitting instrument and Fig. 44-44 shows the transmitter proper.

Under the trade name of "Autosyn" the Pioneer Instrument Co. manufactures position motors characterized by small size and light weight. A typical motor is shown exactly half-size in Fig. 44-45; it weighs 9 ounces. Fig. 44-46 shows how the back plate of a transmitting motor assembly (at the left) is arranged to take various primary measuring elements interchangeably, the element at the right being a Bourdon tube type of pressure gage. Fig. 44-47 shows a "tandem" receiver (without graduated dial) suitable for twin-engine

Fig. 44-45

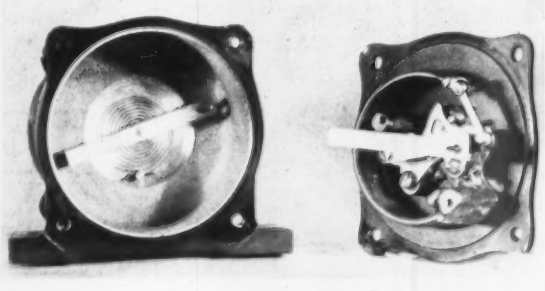

Fig. 44-46

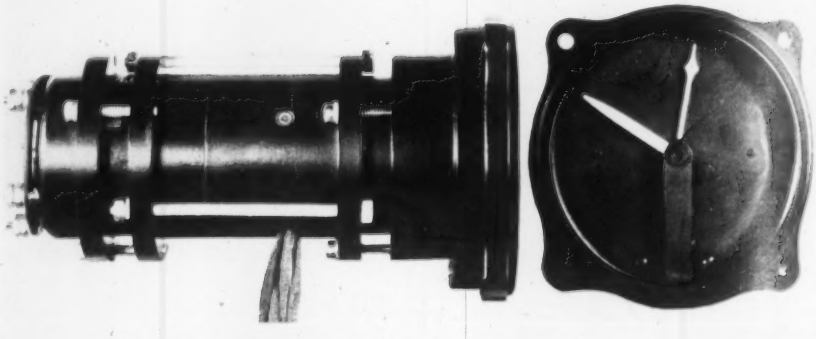

Fig. 44-47

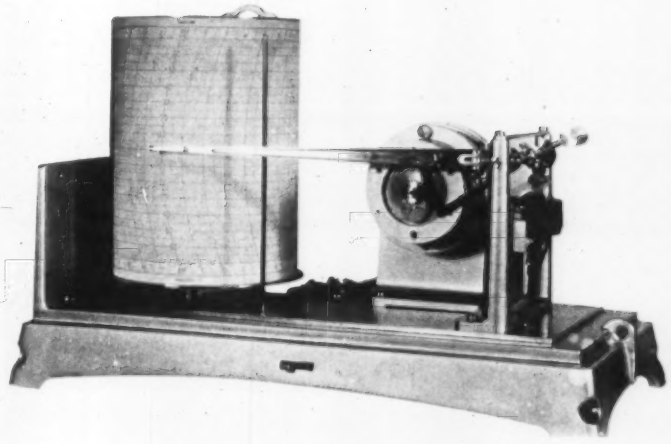

Fig. 44-48

aircraft, forebay and tailrace water levels, etc. Fig. 44-48 shows a drum-chart recorder form of receiving section with an "Autosyn" receiving element.

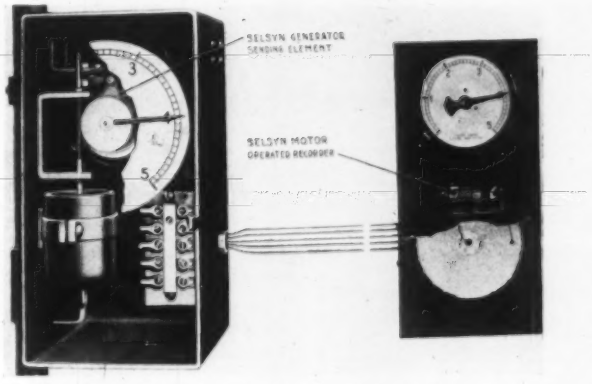

Fig. 44-49

The Bailey Meter Co. employs selsyn motors for telemetering pressures, flows, etc. Fig. 44-49 shows such a system with a mercury manometer primary measuring element in the transmitting section, and an indicator and a recorder at the receiving end.

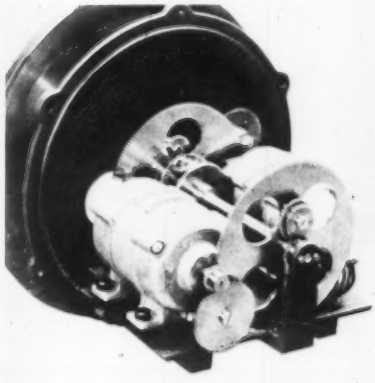

Fig. 44-50

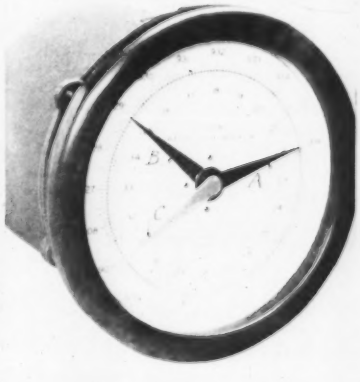

Fig. 44-51

Fig. 44-50 shows a receiver built by Leupold Volpel & Co. to show two distinct water levels, such as forebay and tailrace, together with their difference. Two independent selsyn motors provide indications of the individual levels. A differential gear shown in the photograph operates from its planetary a third pointer whose position is the resultant of the other two, and hence the difference in the two levels. Fig. 44-51 shows the appearance of the dial of the instrument. Pointers *A* and *B* read forebay and tailrace levels respectively on the

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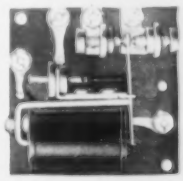

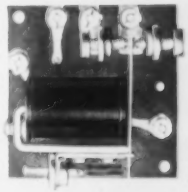

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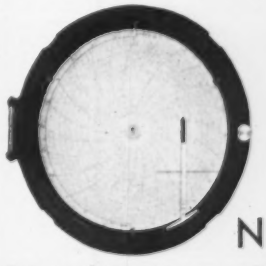

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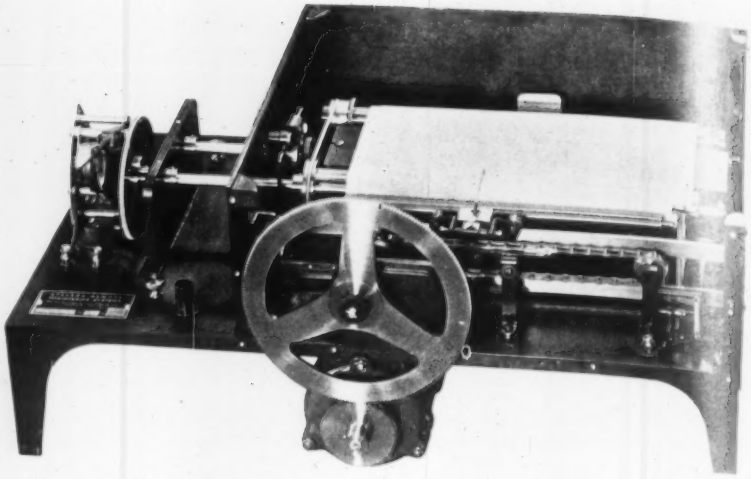


Fig. 44-52

outer scale; and pointer C indicates on the inner scale the head between them. Fig. 44-52 shows a recording receiver built by the same company for producing a record of the rise and fall of distant water levels.

(h) Type 5

Thermal Position-Type System.

A thermal telemetering system, the "Distometer," produced by the Anderson Co., is suitable for various remote measurements where a delayed response is permissible. Its principle will be understood from Figs. 44-53 and 44-54. *A* represents the deflecting member of the primary measuring unit, carrying a contact *B*. Associated with the deflecting member *A* is a bimetallic strip *C*, having upon its extremity a contact *D*. The bimetallic strip is wound with a heater coil *E* connected in series with the contacts *B,D*. A similar structure at the receiving end of the system includes a bimetallic strip *F* having a heating

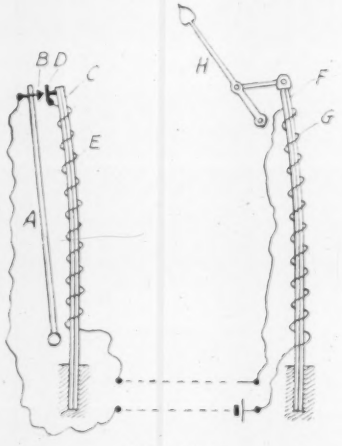


Fig. 44-53

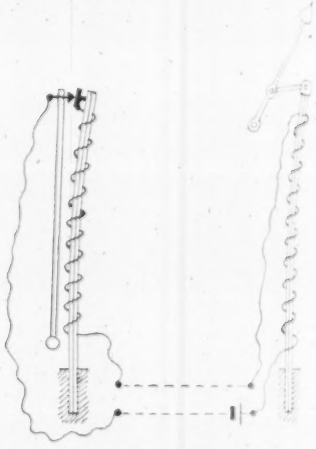


Fig. 44-54

coil *G* and directly linked to a pointer *H*. The operating principle is as follows: With deflecting member *A* in its zero position, contacts *B* and *D* barely engage, causing a current to flow through heating coil *E*. This causes strip *B* to deflect slightly, in a sense to open the contacts. As the circuit is broken the strip cools and re-engages the contacts. Thus strip *B* is continually in a slight vibration. The heater coil *G* in the receiving instrument is connected in series with coil *B* through the interconnecting line, so that strip *F* tends to take up the same position as strip *B*, and maintain the pointer at the zero point of the scale.

As element *A* deflects up the scale, it tends to follow strip *C*, so that a greater mean value of current is required to establish the vibratory condition, with the strip deflected in the direction of the pointer. This greater mean value of current flowing in coil *G* tends to hold strip *F* in a position similar to that of *B*, so that the pointer in the receiving instrument tends at all times to duplicate the position of that of the transmitter.

*U. S. Patents No. 1,885,048, Oct. 25, 1932, F. M. Slough; No. 2,022,440, Nov. 26, 1935, F. M. Slough.

Inspection of Textiles Used for Electrical Insulation Purposes

By J. VAN LAETHEM and R. VERNIMMEN
Bell Telephone Mfg. Co., Antwerp, Belgium

IT is well known that textile insulating materials, owing to their fibrous nature which permits ready absorption of moisture from the atmosphere, are particularly subject to considerable change in their insulation properties as a result of fluctuations in atmospheric temperature and humidity. The effect of humidity on the resistivity of textiles is governed largely by the structure of the fibres. Another well known factor, which to a great extent determines the relative excellence of the insulation, is the electrolytic salt content of the textile. Fluctuations in the electrical behavior of the insulation, resulting from changes in the relative humidity of the atmosphere, may be particularly large and sudden with unimpregnated wire.

The requirements generally imposed for textiles used for wire and cable insulations may be divided into three categories, *viz.*, mechanical, chemical, and electrical. Tensile strength, elongation, yardage, absence of acidity to avoid corrosion of the insulated conductor, moisture content, and electrical resistance are the outstanding features as regards the quality of the material, and are generally covered in raw material specifications. It is not the purpose of this article to give a complete analysis of all comparative tests to be carried out in order to examine whether the materials supplied are in accordance with the specified requirements, but merely to describe briefly a test procedure particularly tending to simplify the electrical testing of raw materials.

The fact that the resistance values obtained with textile materials are largely affected by the relative humidity of the atmosphere, makes it necessary to condition the samples carefully prior to the test by exposing them for several hours in a humidity cabinet to a temperature and a relative humidity kept within narrow limits until complete equilibrium has been obtained. Care should be taken not to handle the thread itself during its winding on the electrodes in order to avoid contamination by perspiration of the hands and the introduction of a possible source of appreciable error in the readings obtained. If the handling and conditioning of the samples be carried out with the necessary precautions, the resistance measurements on the thread will provide consistent results. However, the procedure is long and not very practical when considering the question from the point of view of raw material testing in the factory, since the length of time involved by well controlled preparatory conditioning makes raw material testing, which has to be carried out frequently on all textile lots supplied, very troublesome. With the intention of making the inspection of the insulation properties of textiles more practical, the testing method described below, which avoids the necessity of conditioning the material before testing and which gives significant indications as to the insulation characteristics of the submitted samples, may be advantageously adopted.

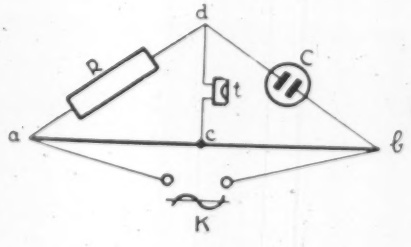


Fig. 1. Kohlrausch Bridge Method of Determining the Conductivity of Extract
R—Resistance Box
C—Cell
ab—Platinum Wire of Uniform Thickness Stretched Along a Graduated Board
c—Sliding Contact
K—Rhumkorff Coil
t—Telephone.

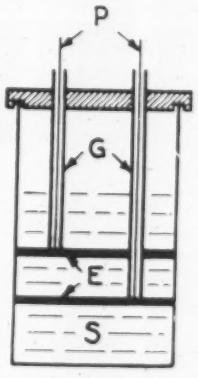


Fig. 2. Arrhenius Type Cell
P—Platinum Wires
G—Glass Tubes
E—Electrodes
S—Extract

FUNDAMENTAL RELATION

Experiments have shown that among the different factors determining the insulation properties of textiles, the amount and kind of water soluble electrolytic impurities which are present in the material, either naturally or as contaminants, are of cardinal importance. Confirmation thereof is obtained by the great increase in insulation resistance obtained with textiles thoroughly washed with water. In consequence of this fact, it will be obvious that the insulation resistance of a textile material will be in close relation with the electrical resistance of an aqueous extract of the electrolytic matter contained in the material. It is common knowledge that the presence of a too high electrolyte content is to a great extent the cause of low insulation resistance of the fibres. Conversely, a low percentage of conducting saline constituents exerts a favorable influence on the final insulating properties of the material. The simplified electrical test procedure developed in order to determine the insulation resistance of the material is based on this relationship.

Experiments were carried out on cotton and silk of different sizes and colors to determine the extent of the relationship for each of the materials examined. For this purpose, several samples of each textile were submitted to two comparative tests, the first consisting in measuring the resistance of an aqueous extract of the material, and the second in determining the insulation resistance of the fibres after carefully conditioning the sample. Quite a fair resemblance, allowing for reasonable experimental errors, was noticed between the quantitative relations found on different samples of the same material. This investigation permits the adoption, for each kind of textile used, of the minimum resistance required on a given aqueous extract of the material that could be considered as giving a definite guarantee as to the minimum specified insulation resistance of the thread. The electrical test on an aqueous extract is added to the raw material specification, together with minimum resistance requirements.

METHOD OF TESTING

The experimental determination of the conductivity of the extract is done by the Kohlrausch bridge method (Fig. 1). The ararngement which in principle amounts to the measurement of resistance by the Wheatstone bridge method, is too well known to need further explanation.

The cell containing the solution, the resistance of which is to be measured, is of the Arrhenius type (Fig. 2). The electrodes are silver or platinum disks covered with platinum black, approximately 4 cm. in diameter and fixed by welding to platinum wires sealed in glass tubes. These tubes are inserted into the ebonite cover of the cell to keep a constant distance between the electrodes. The distance between the electrodes is determined by experiments carried out on the most frequently used textiles, in order to avoid as much as possible making readings at the ends of the logarithmically graduated scale (ab). From the observed electrolyte conductivity, which evidently depends upon the capacity of the cell and thus on the cross section of the electrodes and the distance between them, the specific resistance of the electrolyte specified in raw material specifications must be deduced. First, however, the constant of the cell must be determined. For this purpose a comparison with electrolytic solutions of known conductivity must be made. The results shown below were obtained with a cell of 40.5 mm. diameter and a distance of 10.5 mm. between the electrodes, that is, with a capacity of 13.52 cc. The standard solutions used were potassium chloride and potassium nitrate in the following concentration:

N/50 KCl (1.49 gr. KCl dissolved in 1,000 cc. distilled water) having a specific conductivity of 0.00267 mhos. at a temperature of 25° C.

N/50 KNO_3 (2 g. KNO_3 dissolved in 1,000 cc. distilled water) having a specific conductivity of 0.00248 mhos. at a temperature of 23° C.

Average readings obtained	Temperature	Resistance	Conductivity mhos.
(*a*) With the KCl solution.	25°C.	28ω	0.0357
(*b*) With the KNO_3 solution	23°C.	30ω	0.0333

Constant of the cell to be used for determination of the specific conductivity:

(*a*) Deduced from readings obtained on KCl solution

$$0.00267/0.0357=0.0748$$

(*b*) Deduced from readings obtained on KNO_3 solution

$$0.00248/0.0333=0.0744$$

A mean resistance of 30,000 ohms has been observed for the distilled water used. This has been neglected in the determination of the conductivity of the solutions as it does not affect the value of the cell constant to the four decimal points shown above.

It will be noted that the constants obtained with the two electrolytes were practically the same. The constant of the cell adopted for the determination of the specific resistance of any electrolytic solution and deduced from the specific conductivity of the KCl solution was

$$\frac{1}{0.0748}=13.36$$

All resistance measured on aqueous extracts of textiles, with the cell capacity as adopted, are multiplied by this constant to determine the specific resistance of the solution.

The aqueous solution of the water soluble material content of the textile to be inspected is obtained by the extraction of exactly 2 grams of the textile in boiling water. A solution of 80 cc., corresponding to the total capacity of the cell, is used. The external windings of the spool may not be used for the extraction, since the almost certain contamination of the windings, due to handling, is likely to be a source of incorrect readings. The extraction is performed in two stages. In the first extraction, approximately 45 cc. of distilled water, together with the sample, is placed in a 150 cc. Pyrex beaker and heated to the boiling point. Care is taken during heating to have the textile carefully pressed by means of a small glass rod in order to facilitate the extraction of the conductive salts. The solution obtained is poured into a graduated cylinder. Before starting the second extraction, the textile is pressed with the glass rod to eliminate the solution absorbed by it; this eliminated quantity of solution is added to that in the graduated cylinder. A second extraction, similar to the first, is then performed on the same sample by adding to the Pyrex beaker a quantity of distilled water equal to the difference in volume between 80 cc. and the volume already contained in the graduated vessel. Care should be taken to bring the extracted solution up to the mark with cold distilled water in order to obtain a final volume of exactly 80 cc. The resistance of the solution is measured at a temperature of 25° C.

A large number of comparative tests carried out on different kinds and sizes of textiles made it possible to prescribe the following values of minimum resistance for the aqueous extract, obtained as described above from each of the materials considered. These values were fixed so as to give complete assurance regarding the insulating properties required from the material.

Textile	Min. resistance allowable on aqueous extract (obtained with Arrhenius cell described)	Corresponding specific resistance of the extract (constant of the cell 13.36)
Soft, glazed, and mercerized cotton, white or colored.	1,375 ohms.	Appr. 18,400Ω cm./cm.²
Natural silk, white.	2,000 ohms.	Appr. 26,700Ω cm./cm.²
Natural silk, colored	1,200 ohms.	Appr. 16,000Ω cm./cm.²
Cellulose acetate silk	3,000 ohms.	Appr. 40,000Ω cm./cm.²

Experiments have shown that textiles meeting the above requirements give at least the following insulation resistances measured on the fibres after conditioning of the samples:

Size and kind of textile	Min. insulation resistance allowable after careful conditioning of the material at a relative humidity of 85% prior to testing
20/1 cotton (wound in multiple ends)	8,000 megohms per end
36/1 cotton (wound in multiple ends)	14,400 megohms per end
20/2 cotton	4,000 megohms per twisted thread
30/2 cotton	6,000 megohms per twisted thread
40/2 cotton	8,000 megohms per twisted thread
60/2 cotton	12,000 megohms per twisted thread
200/2 natural silk (white)	950,000 megohms per twisted thread
Cellulose acetate silk (wound in multiple ends)	7,000 mega-megohms per end and per denier

Continued on page 339

Fluorescent Screens for Cathode-ray Tubes

Sixth part of "The Cathode-ray Oscillograph and Its Application" being published serially in *Instruments*. This series began in the July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

LUMINESCENCE

Cathode rays are capable of producing chemical and thermal effects, and may also exert mechanical pressure by reason of their impact. The production of light by the action of the rays on certain luminescent materials is a chemical reaction[1] caused by the breaking up and subsequent reuniting of the molecules upon which the individual electrons strike. It is generally believed that it is the recombination of the molecular components that produces fluorescence and phosphorescence. The rays have a deoxidizing (reducing) effect.

The rays always have identical properties, no matter what type of gas may be within the tube, or what type of filament coating is used on the cathode. Many colors, however, may be obtained with different materials. Marked changes in color can be produced by comparatively minor changes in the chemical structure. The term fluorescence was based on the property of fluorspar of emitting light when heated. The effect can also be produced in some substances by the action of light, heat, radium, X-rays, chemical reactions and physical reactions (such as that produced when certain crystals are broken or agitated).

The record left on photographic emulsion by the direct action of the rays, when a film is placed inside the tube in the path of the ray, is due to a chemical reaction. The thermal effects are not so important for oscillographic work but are becoming useful in many other fields. Electrons, each having a definite mass and traveling at a high velocity, dissipate their kinetic energy as heat. Assuming that no energy is used up in producing the fluorescent effect, the amount of heat energy

$$E = N\ (\tfrac{1}{2}\, m\, v^2) = \frac{I\, v^2}{2\, e/m}$$

where N = number of electrons impinging in a unit time, m = mass of an electron, and I = current in the ray.

FLUORESCENT SCREENS[1, 2, 3]

While the cathode ray carries considerable energy, and is capable of transmitting heat, etc., it is invisible. The glow discharge between the cathode and anode and between the anode and screen, which is visible in some tubes (this effect is most evident in gas focused tubes) should not be confused with the cathode-ray stream. The latter is invisible in itself, but its path can be distinguished because of the fluorescent action of ionized gas molecules.

TABLE I

*Salts**	*Color of Fluorescence*	*Best Exciters*
Zinc sulphide	yellow green	UV
Zinc sulphide	yellow green	CR
Zinc sulphide (special treatment)	blue white	CR or UV
Calcium sulphide	deep blue	UV
Synthetic willemite	yellow green	CR†
Sodium fluoride	yellow	UV or CR
Calcium carbonate	orange	CR
Uranyl potassium sulphate	yellow	UV or CR
Sodium chloride (Type A)	pink	CR
Sodium chloride (Type B)	bluish white	CR
Aluminum oxide (Type A)	red	CR
Aluminum oxide (Type B)	yellow green	CR
Magnesium oxide	(blue—low vacuum (red—high vacuum	CR
Zinc chloride	green	UV
Cadmium chloride	pink, red afterglow	UV
Cadmium sulphate	yellow	UV or CR
Calcium tungstate	blue	CR or XR
Calcium oxide	red	CR
Mercury bromide	orange	CR
Cuprous iodide	violet red	CR
Potassium iodide	green	CR
Lead sulphate	blue	CR
Sodium bromide	bluish white	CR
Sodium iodide	greenish white	CR
Potassium chloride	bluish white	CR
Magnesium sulphate (Type A)	red	CR
Zinc sulphate (Type A)	red	UV or CR
Zinc sulphate (Type B)	white	CR
Zinc sulphate (Type C)	blue	CR
Calcium fluoride	green	CR
Phenocite	blue	CR
Cadmium silicate	orange	CR
Calcite (B)	violet	CR
Calcite (OO)	red	CR
Calcite (L)	green	CR
Sodium carbonate	green	CR
Minerals		
Natural willemite	yellow green	UV or CR
Kunzite	orange	CR or XR
Calcite (MP)	orange	CR
Calcite (ST)	green	CR
Calcite S	orange red	CR
Fluorite	green	CR, UV, XR
Cyanite A	yellow	CR
Cyanite B	red	CR

*The color depends on the concentration and type of activator; a given base material will fluoresce with different colors. Variations are designated A, B, etc.

†Fast rate of decay.

[1] Bancroft. Chemical Production of Light. *Journal Franklin Institute*, Vol. 175, 1913, pages 129-149.

[2] The following references give many general data on fluorescence:
International Critical Tables, Vol. 5, page 386. McGraw-Hill Book Co., 1929.
Nichols & Merritt. Studies in Luminescence. Carnegie Institution of Washington.
Nichols, Howe & Wilbur. Cathode-Luminescence. Tables on Fluorescence. Carnegie Institution, Washington, D. C., 1928.

[3] See also:
Tanaka. Cathedoluminescence. *Journal Optical Society of America*, Vol. 8, 1924, pages 287-318.
Giesel & Zenneck. Die Verwendung des Zinksulfides des Braunschen Rohren. *Physikalische Zeitschrift*, Vol. 10, 1909, pages 377-379.
Kondatzki, Schleede & Schroter. Ueber die Ausbeute an sicht barem Licht bei der Erregung von Phosphoren mit langsamen Kathodenstrahlen. *Physikalische Zeitschrift*, Vol. 27, 1926, page 392.
Tomaschek. Über die Fluoreszenz der reinen Salze der Seltenen Erden. *Physikalische Zeitschrift*, Vol. 34, 1933, pages 374-376.
Perkins & Kaufmann. Luminescent Materials for Cathode Ray Tubes. *Proceedings—Institute of Radio Engineers*, Vol. 23, 1935, pages 1324-1333.
Fonda and Collins. Cathode Ray Tubes in X-Ray Spectroscopy. *Journal American Chemical Society*, Vol. 53, 1931, pages 113-125.
Rogowski, Sommerfeld & Wohman. Empfindlicher Glühkathoden Oscillographen für Innenaufnahmen. *Archiv für Elektrotechnik*, Vol. 20, 1928, pages 619-624.
Plucker. Fluorescence. *Annalen der Physik*, Vol. 103, 1858, pages 88-106.

It has been shown that a beam of cathode rays consists of a stream of electrons shot out through the anode. It is not, at any instant, a body of matter as is a stream of water issuing from a nozzle, but rather like a sand-blast consisting of a large number of individual particles falling at random over the surface of the "spot." It carries enough energy to disintegrate certain chemical compounds—or at least the particular molecule of that compound upon which the electron happened to fall. After accomplishing this much, its energy is spent, and the component elements of that particular molecule are left to recombine again, until such time as another electron happens along. In fluorescent substances this recombination is rapid and when it takes place a bright glow is emitted. In certain other substances the action is slow and the effect is one of phosphorescence. The two effects are similar, differing only (as far as this action is concerned) in the time taken to recombine, and the line of demarcation is not well defined.

It is possible that phosphorescence is always present and that the afterglow aids in making the trace of the beam more apparent to the eye. If there is too much of it, however, the recurring movements of subsequent waves may tend to obscure the pattern. It also blurs photographic records on a moving film.

It is found that the more rapid the recombination of the elements, the brighter the fluorescence. Some of the common compounds, used for their strong fluorescent properties in cathode ray tubes, are listed in Table I.

Taking up the various salts listed in the table, a few additional notes may be of interest. Zinc silicate is fluorescent in either the native state: willemite ore, the orthosilicate $2\,ZnO{\cdot}SiO_2$, or the synthetic crystals—metasilicate ($ZnO{\cdot}SiO_2$), although carefully prepared crystals of the latter are somewhat more sensitive. Often, a small quantity of other salts will improve the brilliance, as for instance tellurium nitrate. Impurities may be driven off without destroying the fluorescent properties by heating to redness, in the case of nearly all inorganic fluorescent materials.

In Fig. 1 the actinic characteristics of a standard willemite screen, from data published by the RCA, is shown by the shaded curve. The normal visual curve of the eye is also shown for reference. The color sensitivity of three types of photographic plate emulsions, under ordinary operating conditions is shown by the three curves: *O*—ordinary or standard emulsion; *C*—orthochromatic; and *P*—panchromatic plates. The use of the correct type of plate in many cases may obviate the need of a special actinic screen for photographic recording.

Special screens are now available with many makes of

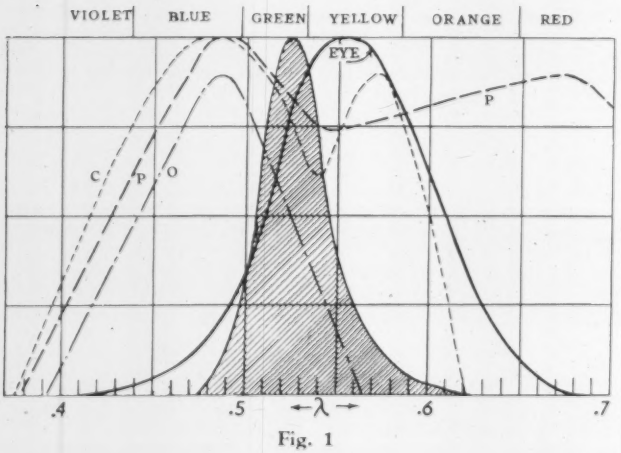


Fig. 1

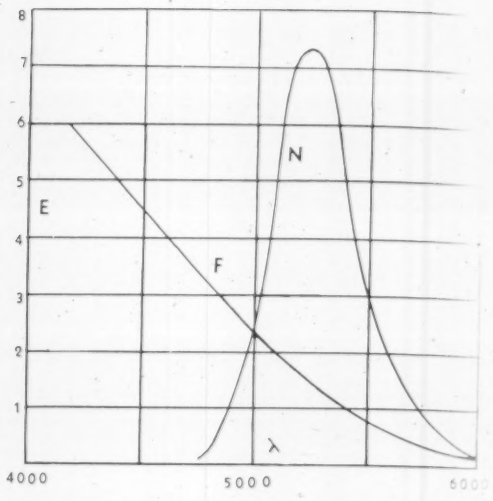


Fig. 2

tubes, which are several times as effective in photographic recording. In Fig. 2 a comparison is made between the wavelengths of the normal willemite or green colored screen, marked *N*, and the fast screen adopted for photographic uses *F*, taken from curves published by the RCA. In interpreting such curves it must be mentioned that the cut off point for any wavelength is not a definite line as shown, but is gradual, the curves representing trends only. The ordinates of the curves in Fig. 2 are not necessarily to the same scale.

DECAY CURVES

Beside having different actinic intensity, the "slow" screen and "fast" screen have different decay periods. A normal screen, as is characteristic of most of the willemite screens, has relatively large phosphorescence, which might give trouble in photographic recording on a moving film. The "fast" screen has a decay period of less than 25 microseconds. When a phosphorescent effect exists, the persistence actually depends somewhat on the initial excitation strength. From rough computations based on photocell measurements on normal willemite screens, it seems that the decay (expressed as a percentage of the initial brilliance) is proportional to 0.00125 divided by the time interval, in seconds, after the removal of the excitation.

Much has been published recently on slow and fast screens. Inasmuch as there is no definite standard of reference, the following definitions will be used here:

1. Fast screens have a decay period of the order of 100 microseconds or less.
2. Normal screens have a decay period of the order of 0.02 second.
3. Slow screens have a decay period of the order of 0.5 second or more.

SCREEN TECHNIQUE NOTES

CaS gives a brilliant trace especially when excited with a strong bombardment, but for weak rays $CaWO_4$ may give better results. ZnS has a somewhat greater phosphorescent action so the trace remains somewhat longer on the screen. Combination salts can be made to possess strong phosphorescent effects often lasting for minutes.

The preparation of the material, its purity, fineness and the type of binder used, all contribute to the results, so that reports on one substance by different investigators vary somewhat with regard to fluorescent action.

Fig. 3

Many other materials that have been found to glow under the action of ultraviolet and other types of radiation might be used. In selecting a material, the sensitivity to such bombardment is of prime importance, but permanence must also be considered, and it must not disintegrate when heated during the evacuation process, as organic materials will do.

It may be found advantageous to combine two or more substances to produce a glow suitable for either photographic or visual work, such as has been done in the Western Electric Type 224 tube, in which a mixture of calcium tungstate and zinc silicate is used. It also is possible to combine a fluorescent material with one that exhibits phosphorescence in certain ratios to increase the "apparent" brightness for visual work.

Technique varies in the matter of depositing the substance permanently on the surface of the glass or mica. Ordinarily the finely powdered material is sprayed or painted on after being mixed with a suitable binder, such as enamel or waterglass. Inasmuch as many of the binder cements discolor under the intense heat of the cathode ray when the spot remains stationary for an interval, the fluorescent material is often floated on in a solution of pure water which is evaporated. In some cases the powder can be dusted on after the surface is freshly coated with the cement. The materials used for binding oxide coatings in vacuum tube cathodes are used also. It has been suggested that potassium silicate has advantages over sodium silicate (waterglass) as a binder.

It is not necessary that a thick coat of the salt be applied as it is the surface only that is acted upon by the rays, and the fluorescent spot must be visible on the opposite side of the screen. For this reason, the screen should be as translucent as possible.

Tests have indicated that a certain grain size (rather larger than that suitable for such screens), gave a more intense fluorescence, but the luminosity when viewed from the back side was considerably reduced by reason of the decreased transparency of the larger crystals. Materials and methods used for X-ray fluoroscopes are suitable also for this purpose.

Fig. 3 shows the tube used in these tests: fitted with a ground joint in order that various fluorescent materials could be inserted.

Since the fluorescent action of any particular material depends upon a transformation of energy the actual brilliance is proportional to the "mass" of the electrons in the jet multiplied by the square of their velocity at the instant of impact. Since electrons are identical, their mass may be considered as proportional to their number. The velocity is in general proportional to E_a so that the brilliance $= k N E_a^2$, where $k =$ the fluorescent constant of the material, $N =$ the number of electrons striking the screen per unit area in a unit of time (*i.e.* the current density) and E_a refers to the anode potential. With low velocity rays, this relation must be modified somewhat, as there is some energy loss in the transformation (probably due to thermal action), with the result that a certain energy level must be reached before any visible fluorescence is noticed, as brought out in the studies of Lenard. The amount depends upon the material used on the screen and its temperature. The above relation is thus equal to $(k N E_a^2 - k' N)$ where k' is also a constant depending upon the fluorescent material.

Except in unusual cases it will be found that no fluorescence is produced below a certain anode potential. While the above relation may be partially responsible, the main effect is due to a negative charge accumulating on the screen and walls, which repels the slow-speed electrons and prevents their reaching the screen.

PHOTOGRAPHIC SCREENS

As indicated in the table, the type of material on the screen is important in the photographing of diagrams. When clear pictures are required with a short exposure, permanently sealed off tubes (as distinguished from tubes that are arranged so that a film is inserted directly in the cathode ray stream) should:

(1) have screens coated with a material active photographically, such as $CaWO_4$;

(2) use a high accelerating potential.

A possibility has been suggested of having the end of the tube opposite the screen composed of fused quartz or a type of glass that passes the shorter wavelength radiations.

For visual work with inexpensive tubes, it is possible to "get by" without a screen, using the fluorescence of the glass as the indication of the path. The Corning Glass Co. has developed a special glass that fluoresces with a bright canary color when activated, although any glass will fluoresce more or less.

It has been stated[4, 5, 6] that satisfactory results were obtained with a fluorescent screen composed of a mixture of sulphur and minium (presumably Pb_3O_4) dusted on the external surface of the bulb. The passage of the "spot" over the inside surface of the glass leaves a charge, and the fine powder clings to the outside of the glass along the path of the "spot." The powdered sulphur (yellow) provides color contrast.

It has been suggested that for certain uses where a slowly disappearing phosphorescence is required, a thin layer of phosphorescing material can be coated on the outside of the screen, to be energized by the luminosity of the inner fluorescent screen.

The energy transmitted the length of the tube can be collected on a metallic screen and measured. It has been suggested by Langmuir that many measurements (such as of power) can be made by comparing the energy collected by various parts of a metallic screen cross divided into sections. This principle has been utilized by Zworykin in his television tube, the Iconoscope. Langmuir also mentions[7] a screen of a refractory metal which would be heated to incandescence by the impinging rays and the path thereby made visible.

CALIBRATION SCALES[8, 9]

In making measurements and in copying diagrams from the screen, a transparent template or scale, arranged to be placed against the screen, is often useful.

[4]Selenyi, Ueber die durch Kathodenstrahlen bewirkte elektrische aufladung Glasen. *Zeitschrift für Technical Physik*, Vol. 9, 1928, pages 451-454.

[5]Selenyi, Ueber die weitere Entwicklung der neuen mittels elektrostatischer Ladungen. *Zeitschrift für Technical Physik*, Vol. 10, 1929, pages 486-489.

[6]Schnabel, Fluorescent Materials for Television and Cathode-ray Oscillograph Uses. *Archiv für Elektrotechnik*, Vol. 28, 1935, pages 759-767.

[7]Langmuir, Focusing Electrode and Screen Design. U. S. Patent No. 1219661.

[8]Wood, The Cathode Ray Oscillograph. *Journal Institute of Electrical Engineers*, Vol. 63, 1925, pages 1046-1056.

[9]MacGregor-Morris & Mines, Measurements with the Cathode Ray Oscillograph. *Journal Institute of Electrical Engineers*, Vol. 63, 1925, pages 1056-1096.

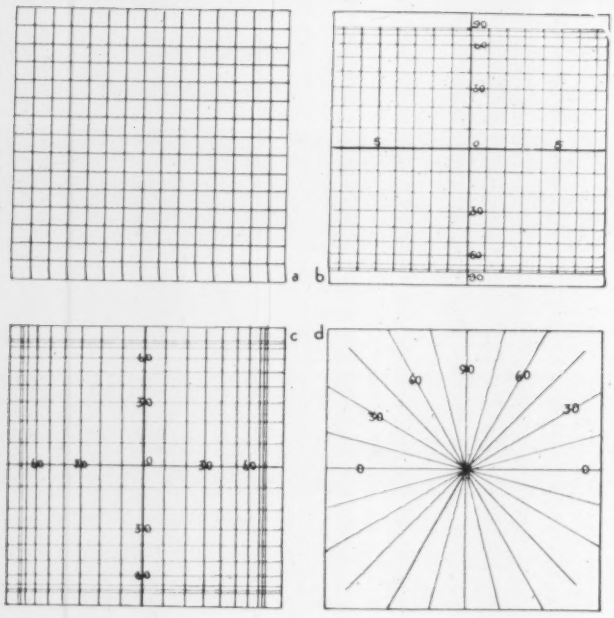


Fig. 4

Fig. 4 shows reproductions of a number of such scales.[10] The holder can be attached to the shield of the mounting stand so that it can be rotated in a plane parallel with the screen. The markings must coincide with the axes of the figure, and so may be shifted up and down and back and forth a small amount.

The scales are on transparent celluloid and are engraved and filled in with black ink. In some cases it is desirable to roughen the surface of the scale somewhat so that records can be written down immediately, and the diagram traced directly on the scale. Permanent records can then be made by blueprinting.

The scales illustrated are representative of the graduations found particularly useful. In Fig. 4a both vertical and horizontal lines are provided. Inasmuch as the actual calibration of the deflection may not be constant over the whole surface of the screen (a point dealt with in the August article) it is desirable to graduate the scale from the experimental calibration data. In Fig. 4b the horizontal deflection is graduated as a sine scale (useful when a sinusoidal time base is used). In such applications it is necessary to adjust the amplitudes of the timing wave to correspond with the maximum value of abscissa. In 4c the divisions in each direction are in accordance with the sine law. A fourth type (4d) is used with circular or polar time base. Many other scales will suggest themselves which may be used on occasion, such as logarithmic, etc.

When the tube has a screen coated on a sheet of mica, care must be taken so that parallax does not affect the reading of various deflection amplitudes, since a considerable distance is found between the screen and the scale parallel with it.

In calibrating a tube using deflection plates, a series of steady and known voltages, having definite steps in value, are applied in one direction, while alternating potentials of sufficient value to produce full-scale deflection are applied in the other direction. A series of lines are obtained, which should be parallel with one another.[11, 12]

[10] Batcher. Applications of the Cathode Ray Oscillograph. *Proceedings Institute of Radio Engineers*, Vol. 20, 1932, pages 1878-1891.

[11] Wilmotte. A Method of Measuring Cathode Ray Tube Figures. *Journal Franklin Institute*, Vol. 209, 1930, pages 809-813.

[12] MacGregor-Morris & Wright. Accuracy of Measurements with Gas Filled Cathode Ray Tubes. *Journal Institute of Electrical Engineers*. Vol. 71, 1932, pages 57-82.

The connections are then reversed and the [illegible] repeated, whereby a coördinated screen is obtained as a calibration for the deflections. By making the [illegible] potential increments exactly integers (say fives or [illegible] volt steps) this graph can be transferred to a transparent piece of celluloid as in Fig. 4a. A screen of this [illegible] can be placed against the diagram and potential producing any deflection can be determined directly.

SHAPE OF SCREENS

Curved screens with the fluorescent material coated directly on the inside of the glass are usually provided. There has been much more concern about the error introduced by such a screen than conditions warrant. For extreme accuracy (if such is possible with this type of oscillograph) it is of course necessary to make some

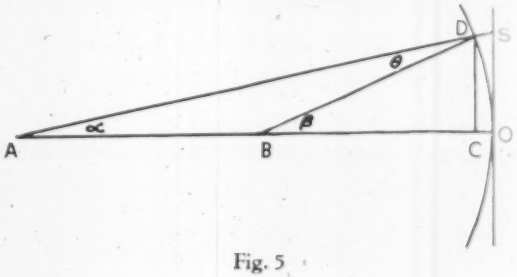


Fig. 5

allowance, but one must know the equation for the profile of the screen (sometimes the segment of a sphere of radius *r*, Fig. 5). It is found, however, that the correction is rarely large enough to bother with in tubes of normal length, as will be shown.

Partial compensation is made by making measurements directly along the glass, which gives a value more nearly equal to the true deflection than any other measurement. *No correction at all is necessary when all points of the diagram lie approximately equidistant from the center.*

It can be shown that still another effect is present which introduces an error of equal rank with the foregoing. It might actually compensate to some extent for the effect of a curved screen. When an electron moves through an electrostatic field at an angle, it is influenced to a greater extent than if it had proceeded straight through, since the length of path is longer. The sensitivity thus depends upon the deflection, and a ray deflected somewhat by the first pair of plates is deflected by the second set of plates more than a ray not deflected initially.

This effect is small and difficult to compute or compensate for. It is mentioned to bring out that all cathode-ray tube diagrams have small inherent errors and that major conclusions based on small deviations found from measurements are unwarranted.

The electrostatic deflection sensitivity can be increased in one direction, by the use of a special screen within the tube that is inclined at an angle to the axis of the tube. This might be obtained by the use of a coated mica sheet.

In order to be of greatest utility, however, it is necessary that the jet be focused in such a manner that the difference in the length of the ray path, as deflection occurs, does not upset the focus. It also is necessary that the screen be aligned accurately with the normal axis of deflection. Finally, in order to equalize the deflection so that it will be linear with the deflection voltage it is necessary to warp the screen (*S*) so that the [illegible]

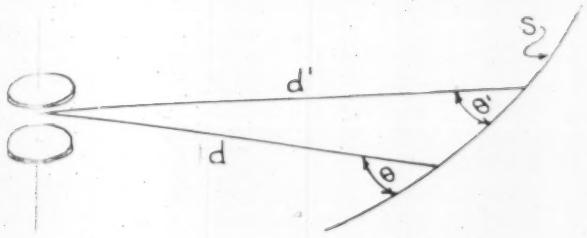


Fig. 6

$$\frac{\text{Cos } \theta'}{\text{Cos } \theta} \quad \frac{d'}{d}$$

is satisfied at each point. As in Fig. 6, "d" and "d" represent the ray paths from deflection plates to the screen.

FREQUENCY ERROR

When high-frequency potentials are applied to the deflection plates a frequency error will be found in the amplitude of the deflections. The frequency at which this error might become noticeable depends upon the anode potential. With low potentials the electrons travel at a slow speed and the deflection will follow different laws from those assumed for the derivation of the charts in the August and September articles and the equations associated therewith.

To illustrate this effect, assume that the length of a pair of deflection plates is two inches, that the anode potential is about 100 volts, and that 60 megacycle potentials are applied to the plates. This is an extreme example as approximately one half period is consumed by an electron to traverse the path between the plates but it illustrates the principle mentioned.

Those electrons that enter the field between the plates at the beginning of a cycle follow a path between the plates approximately that shown in curve *A*, Fig. 7. The ray emerges at *A* at an angle of practically zero and it eventually reaches the screen with a total deflection practically the same as that which occurs between the plates. In other words, there is no magnification. Electrons that enter the field 90° later in the cycle follow a curve somewhat as indicated in curve *B*. Although smaller deflections occur between the plates, the emergent direction is

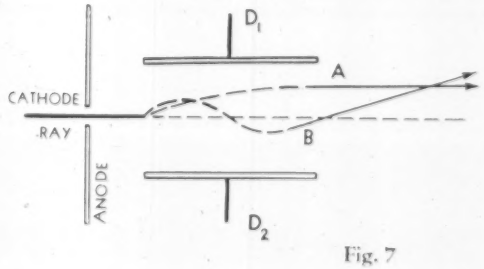


Fig. 7

at an angle with the axis so that the ultimate deflection on the screen is much greater. Since a continuous stream of electrons enters the deflecting field a continuous line will appear on the screen as a result, which will resolve into a solid sine wave upon any transverse movement due to other deflecting forces.

At lower frequencies, say about a tenth of the foregoing critical frequency, the beam focuses in a short line instead of a point, the length of which is greatest when spot is at the center of screen.*

The above analysis is given to point out the effect only as it is not possible to give exact quantitative relations which might serve in making corrections. Higher anode potentials must be used when these frequencies are being investigated.

This effect calls to mind an assumption made in the derivation of the sensitivity formulas: That the total deflection on the screen depends upon the actual value of the deflection that occurs between the plates, whereas it actually depends upon the angular change in direction that the beam has upon leaving the field due to the plates. As long as the speed of the electrons is great enough so that the potential on the deflection plates is substantially constant during the interval taken by an electron to pass between them, this is true, and a tangent to the curvature of the path at the point where it leaves the field will intercept the normal axis opposite the center of the plates.

*This effect is in addition to the lack of focusing at high-frequency deflections in gas focused tubes, which effect is taken up elsewhere.

INSPECTION OF TEXTILES USED FOR ELECTRICAL INSULATION PURPOSES

(Continued from page 337)

The insulation resistance is determined on a thread closely wound on a width of 50 mm. around two gold plated electrodes distanced so as to obtain threads having a free length of 21 mm. between electrodes. The electrical circuit used is shown in Fig. 3. A direct current tension of 105 ± 5 volts is applied. The measuring is done as soon as the galvanometer shows a constant deflection. Care is taken to have the reading noted as quickly as possible (within a time not exceeding one minute).

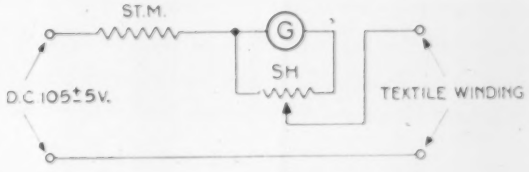


Fig. 3. Electrical Circuit Used for the Measurement of Insulation Resistance

ST.M—Standard Megohm
G—Galvanometer
SH—Shunt of Galvanometer.

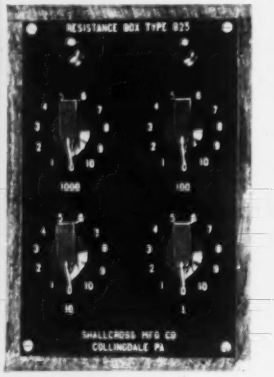
Prior to the test, the samples are carefully conditioned inside a humidity chamber at a relative humidity of 85% and a temperature of 37° C. for a time sufficiently long to obtain complete equilibrium of the material. It may be noted that the testing arrangements adopted with regard to applied voltage, material of electrodes, and measuring time, were taken with a view of reducing to a minimum the effects due to the well known polarization and Evershed phenomena which often lead to anomalous resistance values.

The resistance values specified can only be reached with textiles showing a high degree of purification. Consequently they involve the necessity, on the part of the supplier, for thorough washing of the material. Unwashed textiles often show resistance one fiftieth of the values indicated in this article.

Foxboro Company Expands

The Foxboro Co. has acquired an interest in the Atlantic Precision Instrument Co. of Malden, Mass., makers of "Verigraph" gages for moisture content of paper and thickness of dielectrics. Albert Allen and W. H. Howe of Atlantic go over to Foxboro—the former on "Verigraph" sales and the latter in Foxboro's Research Department.

SHALLCROSS
DECADE RESISTANCE BOXES
Employing accurate wire wound instrument type resistors.



The 800 Series Decade Resistance Boxes find wide application as meter multipliers, bridge arms, determination of replacement resistors in radio sets, electronic tube circuits, and industrial, school and college laboratories.

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NEW INSTRUMENTS

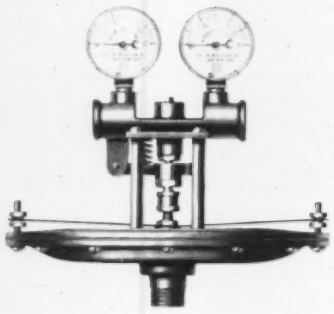
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Static Pressure or Vacuum Regulator

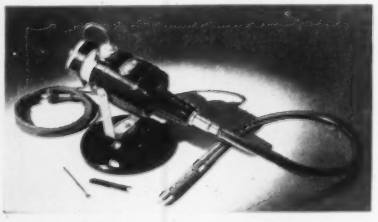
Designed to maintain a constant pressure or vacuum by commanding a damper located in the intake to or discharge from a fan, or by controlling the speed of the fan through a hydraulic coupling



or a pneumatic rheostat coupling, this new device brought out by the Powers Regulator Co. is sensitive to a ¼" water column variation. Adjustment is provided for changing the operating point slightly. Dimensions 9"×9"×9".

Automatic Speed Control for Flexible-shaft Tool

What appears to be the first application of modern speed-control Instrumentation to an inexpensive device driven by a small a-c. motor is found in the "KG Vari-Speed" flexible-shaft tool developed by The Dumore Co. Heretofore, in order to preserve the advantage of having a small grinding wheel, saw, file, cutter,



etc., positively connected to the rotor by flexible shafting, the motor speed was varied by a "power-stealing rheostat." The Dumore Co.'s tool incorporates instead an adjustable electric governor, mounted at the rear of the motor. This automatic speed controller may be set "by a turn of the wrist" for any speed between 1700 and 12,000 r.p.m. Thus no power is wasted, whether the user works on soft wood at the highest speed or on a hard alloy at the lowest setting.

Small Square Instruments

Maximum readability at mid-scale among features of the new "Type 573" line of electrical indicating instruments announced by the Hoyt Elec. Instrument Works. Semi-flush Bakelite case measures

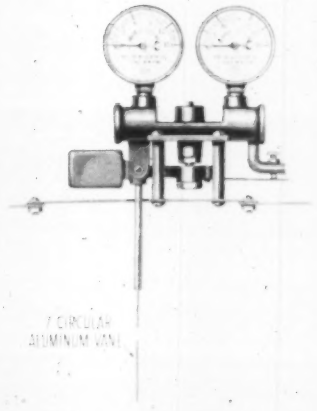
4½" square at front, while body is cylindrical, fitting 2¾" diam. mounting hole in panel. Movement is new throughout, special narrow coil form with pivots inside, supported by sapphire jewels set in core irons. "Type 573" is now available in all commonly-used d.c. ranges. Accuracy is ±2%, sensitivity 75 mv. in the 0-1 ma. range.

Specimen Polisher

An improved type of "Guthrie-Leitz" automatic magnetic polishing machine, designated "Model D," is announced by E. Leitz, Inc. This instrument represents departures from the former model. A few of its features: (1) Specimen holder accommodates one to three specimens at a time. (2) A transmission device causes specimen holder to rotate so that specimen receives motion simulating the one usually produced when polishing by hand. (3) Polishing plate speed range extends from 350 to 1000 r.p.m.; speed can be changed while machine is in action; pointer-and-scale indicate speed. (4) Magnetic pull on specimen can be regulated. (5) Cabinet storage space for entire grinding and polishing equipment. (6) Solution agitator, blowing device and other improvements.

Air Velocity Regulator

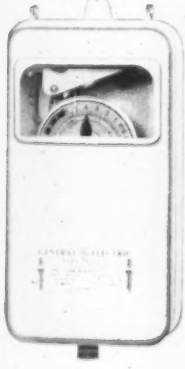
Designed to maintain a constant velocity of air in a duct by commanding a damper located in the intake to or discharge from a fan, or by controlling the speed of the fan through a hydraulic coupling or a pneumatic rheostat coupling, this new automatic controller brought out by the Powers Regulator



Co. consists of a circular vane mounted on a lever which operates a pilot air valve mechanism. The vane, located within the duct in the air stream, may be inserted through the top, side or bottom of the duct. Velocity changes cause movements of the lever which operates the air valve, thereby actuating the diaphragm motor which operates the controlling unit. The regulator can be furnished to pass air with an increase of velocity, or to exhaust air with an increase of velocity. It is provided with supply and damper air pressure gages. It will respond to an air velocity variation of 10 f.p.m. Dimensions: Height 9½", width 5", depth 5".

24-hour Time Switches

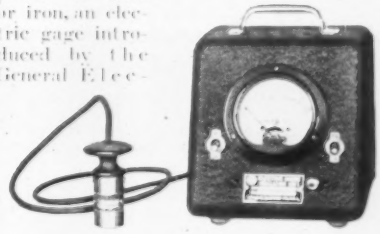
Wide adaptability, simplicity and low-cost installation are said to characterize the new "Types T-17" and "T-27" with which the General Electric Co. rounds out its line of automatic time switches (see *Instruments*, Vol. 6, 1933, pages 88, 178, 179, 227; Vol. 7, 1934 page 103). The former will control almost any electric circuit on a schedule related to the time of day and can be set to skip Sundays and holidays; the latter is not equipped with this omitting device. The standard switches are designed for a-c. circuits, 115 and 230 volts, current rating 40 amps. per contact. Either a plain dial

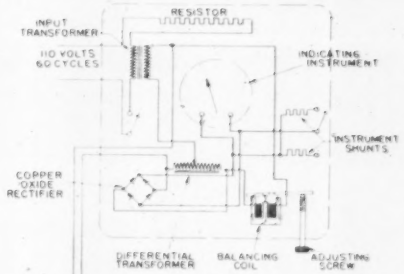


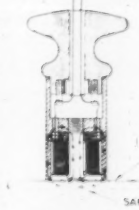
(for fixed time setting) or an astronomic dial (for sun schedules) or certain combinations of both can be furnished. Drive is Telechron motor and spur-gear train. Switching mechanism operates quick-make and -break silver contacts. Program is determined by small riders (clamped to the periphery of the time dial at selected points by means of thumb-screws) which engage switch-tripping lever, thereby alternately forcing contact buttons apart and allowing them to close. An index indicates the position of the switch. These instruments are available in six forms: Single-throw—single-, double-, and triple-pole; double-throw—single- and double-pole; and two-circuit with separate break.

Electric Thickness Gage

For measuring the thickness of porcelain enamel, paint, or other non-magnetic materials such as celluloid, glass, mica, etc., applied to or laid on flat sheets or plates of steel or iron, an electric gage introduced by the General Electric Co., permits quick measurements not only at edges but wherever a flat surface >1" in diameter can be found.

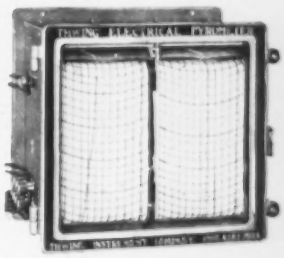






When the face of the gage head is held in contact with the surface of the material to be measured, the thickness is indicated directly. Because of its light weight (½ lb.) the gage head can be moved readily. Operation is based upon the reluctance of a magnetic circuit passing through a coil in the gage head and through the steel under the film; the greater part of this reluctance is produced by the non-magnetic material (or equivalent air gap). The indicating instrument is first adjusted to read correctly with a known thickness of non-magnetic material (or a known air gap) between the gage head and a sheet of steel as used with the material being measured. It can then be used to indicate the thickness of enamel within the range for which it has been set. Standard thickness ranges: 1-5, 2-10, 10-50 and 20-100 mils, a separate scale on the indicating instrument being required for each. Double-range indicating units are available, as is also a unit of modified design for measuring films <1 mil thick.

Thwing Recording Pyrometers



Thwing Recorders are made in single point and multiple recording types. These recorders are calibrated for use with base metal and platinum thermocouples, high temperature radiation tubes and low temperature resistance thermometer bulbs.

Simplicity is an outstanding feature of Thwing Recorders.

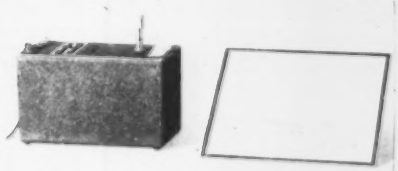
Metal case construction, electric drive, automatic chart reroll, one color ink recording system. Accurate and rugged.

Thwing Recording Pyrometers are easy to use, simply connect the thermocouples to the recorder and clear, easy to read graphic temperature records are made on continuous roll charts.

4-35

Thwing-Albert Instrument Co.
3323 Lancaster Ave., Philadelphia, U.S.A.

The MICROMETER FREQUENCY METER—for measurements in the radio field—is proving its precision and stability in transmitting stations, in educational, manufacturing, and research organizations.



Contributing to the precision is the micrometer with developed scale length of over five feet, and the calibration curve over four feet long.

Contributing to the stability is the micrometer condenser of the cylinder and tube type, the automatic compensator for temperature-frequency errors, and the special ceramic insulation.

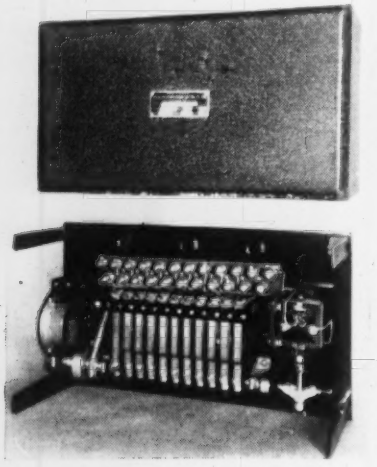
The instrument uses the heterodyne method, is full a.c. operated, and accurate within .02%.

Write for data sheet

LAMPKIN LABORATORIES
BRADENTON, FLA.

Automatic Reset Timer

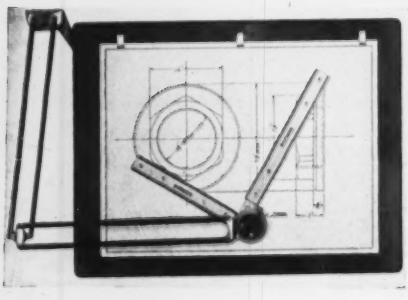
Added safety in starting a series of operations is among features of the Automatic Temperature Control Co.'s new "ATC Reset Time Control." This device starts electrically a series of consecutive or overlapping operations on a desired schedule. In addition to providing accurate timing, the unit is designed to return to original starting position in event of fuse blowout or other power failure.

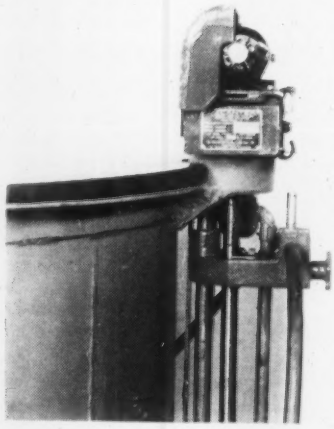


Other interruption, as the failure of an automatic die-casting machine to complete an essential movement, causes the timer to reset and await a signal to restart. The unit illustrated is arranged to start a series of ten electric motors on a schedule which avoids heavy surges in the power line. Other units governing more or fewer than ten operations are available. Timing accuracy is gained by adjustable cam construction and by the fact that starting and resetting actions require no re-meshing of gears. The driving clutch engages the cam shaft instantaneously.

Portable Drafting Machine

Combining a drawing board and a drafting machine, the "Drafto" is made in four sizes, that illustrated taking sheets up to 15"×20" and others 12×18, 10×15 and 9×12—this smallest one fitting a brief case. Any of these can have its mechanism mounted vertically to make it particularly suitable for patent drawings, typographic layouts, etc. Paper clamps do not interfere with movement of scales: scarcely projecting above, they are tightened underneath the board, the screws forming rests which tilt the board at a convenient working angle. Protractor clamping device is said to have been highly perfected. Some scales are detachable. The Drafto Co. announces also two sizes of separate mechanisms ready-to-attach to drawing boards.



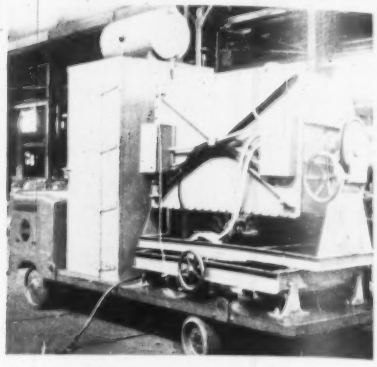


Tank Discharge Control

Rate of flow of liquid from tank bottom is automatically controlled (held constant or varied at will) by the "Decanter" brought out by Proportioneers, Inc. This equipment is either supplied for mounting on a tank in the field, or complete with a tank of specified size. It positions a rubber weir block by means of a motor-driven screw. The motor can be supplied for constant- or variable-speed. An alarm bell is sounded when the weir has approached the low limit of its travel, indicating that the supply of liquid is low. Suitable for handling any liquid, including acids, the unit illustrated can be supplied with rubber lining for handling ferric chloride, etc.

Mobile X-Ray Equipment

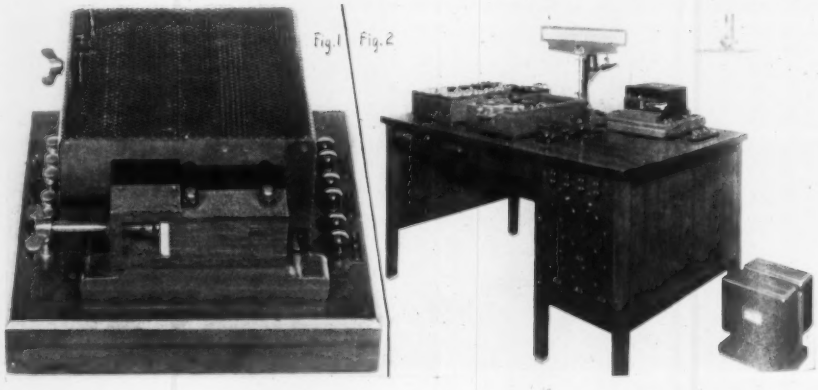
The great weight of boiler [illegible] stills and other large welded pressure vessels to be inspected make necessary to move the X-ray equipment to the vessel and along the length of welds. Large X-ray equipments, because of great weight. Illustration shows solution of this problem in the use of a special electric truck built by the Baker



Industrial Truck Div. of the Baker-Raulang Co. for a 6½-ton X-ray inspection equipment manufactured by the General Electric Co. The motive power of the truck is used only to move it the full length of the vessel being examined; from one job to another the entire assembly of truck and X-ray equipment is carried by the overhead crane available in all shops where large pressure vessels are fabricated or inspected. This permits using the mobile unit in shops with rough floors.

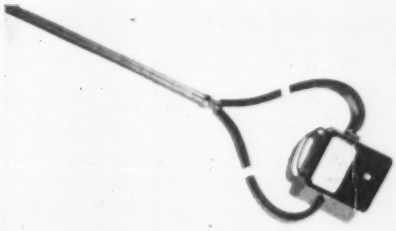
Full-range Permeameter

Wide range, precision, simplicity of operation, and convenient arrangement of instruments and controls are some of the features of a new full-range permeameter equipment announced by the General Electric Co. It is suitable for both research and plant laboratories. In developing new magnetic alloys or in testing commercial specimens, it is employed for determining the magnetization and hysteresis characteristics of magnetic materials. Either sheets or solid magnetic materials may be tested. The normal range of tests is from $H = 0.01$ to $H = 1000$ oersteds but higher magnetizing forces can be attained for short-time periods. This range makes it possible to obtain complete magnetization and hysteresis characteristics of most magnetic materials. Results are reproducible and accuracy of measurement is of the same order as that obtained with present permeameters. The permeameter (Fig. 1) requires but one test specimen, which may be of either strip or bar form, up to $1\frac{3}{16}$" wide (Epstein width) by $\frac{1}{4}$" thick and of any length >10". The test is relatively easy, by reason of the simplicity of the method involved and the convenient arrangement of the instruments and controls. The equipment is assembled in a convenient table form (Fig. 2) completely wired and ready for operation when the instruments are set in place and connected. It is designed to operate from a constant d-c. voltage supply of 120 volts. It consists of the following items: (1) testing table with current control rheostats and switches; (2) magnetic reversing contactors; (3) permeameter; (4) multirange ammeter; (5) compensating mutual inductor; (6) ballistic galvanometer; (7) galvanometer control box and calibrating mutual inductor; (8) galvanometer lamp-stand and scale; and (9) reference specimens.



P. A. Attenuator

Tech. Laboratories announce a new attenuator specially designed for P. A. and portable equipment and said to meet the demand for a low-priced unit of wide range and of remarkably small dimensions (2⅛" diam. x 1 13/16" depth). It has 22 steps of attenuation covering a range of 50 db. It is said to be ideal for use in the laboratory in experiments requiring low d-c. or a-c. voltage, as in chemical, physical and medical research. For instance, by connecting two of these attenuators in series and connecting a 1.5 volt battery to the input leads the output will give voltages from 0.000047 volts. These attenuators can be supplied with special dial plates permitting removal of unit through front panel for easy servicing.

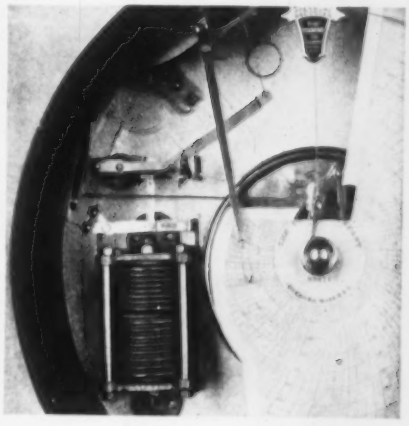


Duct Jet Attachment for Air Velocity Indicator

Illinois Testing Labs., Inc., has brought out the device illustrated in order to convert the "Boyle Velometer" (see *Instruments*, July 1935, page 191) from an open-stream or "wind" velocity indicator into a direct-reading current meter suitable for making velocity traverses of ducts. The attachment has two openings, facing in opposite directions, so that an air-stream filament passes through the indicating instrument and is returned to the same location in the cross-section of the duct. Static pressure errors are eliminated.

Absolute Pressure Gage

The Foxboro Co. announces the development of a new absolute pressure gage having a unique method of compensating for changes in barometric pressure. The pressure measuring and barometric compensation units are mounted together, forming a complete and integral actuating movement. Two "hydrons," one measuring direct pressure and the other barometric pressure, are so connected that their pressures directly oppose each other. The compensating "hydron" which is sealed under full vacuum exactly counterbalances the barometric effect on the main pressure "hydron," permitting the

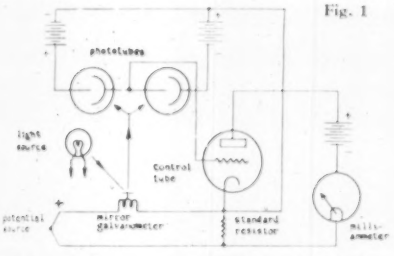


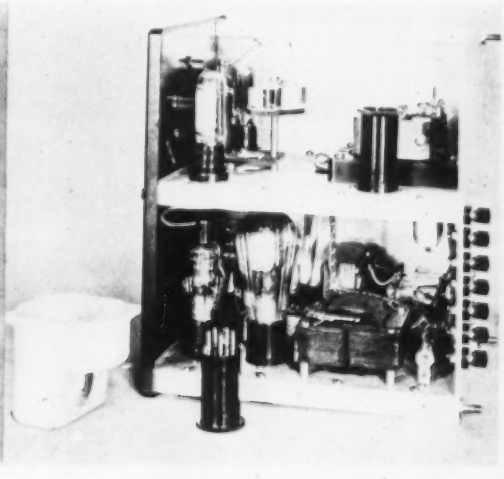
latter to measure only true absolute pressure. This method is comparable with the manometer method of measuring differential pressure, whereas previous methods could be likened to the method of using two pressure gages, a small error in either pressure reading sometimes amounting to a large percentage of the differential. New design does away with all unnecessary linkage. Lost motion is thus eliminated. The new gage is protected against overrange, is light and portable, and contains no liquid to spill or lose its seal. It can be equipped with the Foxboro "Stâbilog" mechanism and used for automatic control.

High-speed Automatic Potentiometer

The balancing circuit is continously and rapidly adjusted by photoelectric control in an automatic potentiometer announced by the Weston Electrical Instrument Corp., which provides a sensitive means for indicating or recording voltage or current at ranges as low as 2 millivolts or 5 microamperes full-scale, or even lower if required. It is said that temperature, pH and other magnitudes convertible into small values of electrical input may be indicated, recorded or controlled with a speed and precision hitherto unattainable. The instrument furnishes an indicating current capable of operating at any distance a number of indicators, recorders, control relays, etc. It contains no moving parts other than the galvanometer itself, which has no control torque and is free of zero drift. Deflection of this mirror galvanometer varies the relative illuminations of a pair of phototubes in a bridge circuit (Fig. 1) connected to the grid and cathode of a vacuum tube and so arranged that the changing light differential between them results in a change of grid voltage. This change in grid voltage, in turn, electronically readjusts the indicating current to balance the circuit across the standard resistor. The circuit will hold itself in balance constantly, and immediately readjust itself for any change of input value. Balance involving a full-scale change in indicator deflection is said to take place in a fraction of a second. This system of balancing is independent of elements other than the value of the standard resistor and the instrument giving the final readings. Changes in supply voltage, vacuum tube characteristics, photocell efficiency, light source intensity, etc., lie outside the critical circuit. Thus the instrument can be used on the regular power supply and need not be checked against a standard cell. The standard resistor is arranged for plug-in connection, so that the range of the instrument can be changed at will.

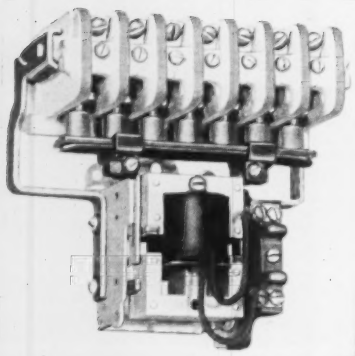
Fig. 1





Piezoelectric Calibrator

Accurate checks of oscillator frequencies are made possible by means of a new crystal calibrator announced by RCA Parts Div. of RCA Mfg. Co. This is a special crystal oscillator with two frequency modes (100 and 1000 kc.), each having prolific harmonics. Its temperature coefficient is 20 cycles/kc./°C. It uses one RCA-955 acorn type Radiotron. Power supply required is 110-120 volt, 50-60 cycle a.c. (90-135 volt d-c. plate supply may be connected externally for unmodulated operation if required). Power consumption, 2 watts. Size, 5¼"x 3⅞"x2⅝". Weight, 19 oz.

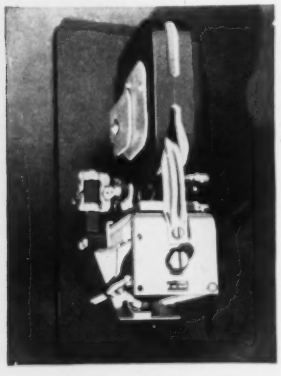


Multipole Magnetic Contactor

A compact new multipole magnetic contactor, designated as Size 0 and rated 2 h.p., is announced by the General Electric Co. It is intended for use either with small single-phase and polyphase a-c. motors, or as a flexible relaying device for complicated control systems, such as are used on machine tools. It is available with either normally open or closed contacts, or with a combination of both. It may be controlled remotely through push-button stations, limit switches, or other pilot devices. Any two forms of the contactor may be combined and mechanically interlocked either vertically or horizontally. It can be mounted either as an open-type contactor or as an enclosed switch, being obtainable also with enclosing cases.

Mill-type D-c. Contactors

A new line of d-c. contactors intended for the severe service encountered in steel-mill applications has been brought out by the General Electric Co. Desig-

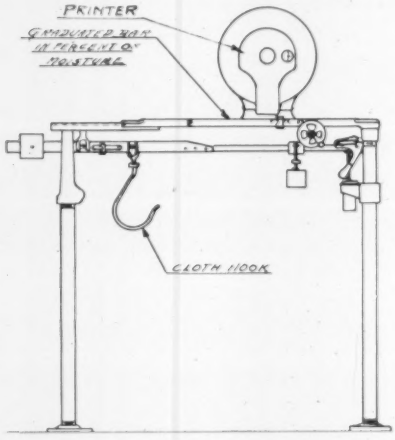


nated as "CR-2800," they are equipped with rocker bearings, which are practically unaffected by wear. They are constructed of heavy cold-rolled steel and are designed to facilitate inspection of parts. All frames are drilled for mounting mechanical and electrical interlocks so that these devices can be added, if desired, after installation.

TUBULAR RHEOSTATS
COMPLETELY RECONDITIONED
Single and Double Slide Types
Some Screw Drive—8", 16" and 20"
ALL RANGES
Your inquiry for one or a thousand invited.
LOUIS J. WINSLOW
134 Sussex Ave. Newark, N. J.

Moisture-content Computing Weigher-printer

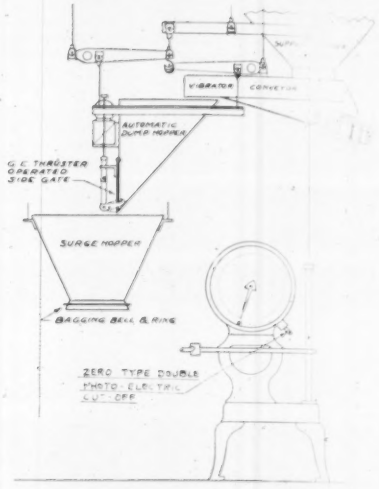
An automatic weigher which indicates and prints what a piece of cloth would weigh with a definite moisture content has been developed by the Toledo Scale Co. Essentially it is a modification of the Toledo Variable Leverage Auto-Gage, so



arranged that when, for example, a bolt of cloth with a known actual moisture content is placed on it, the indication represents what that bolt of cloth would weigh if it had the percent of moisture on which commercial transactions are based. Through operation of a Toledo Printweigh this same base weight may be printed on a ticket, on a tape inside the device, or on both. Drawing shows application for bolts of rayon cloth, but equipment is suitable for bales of cotton, wool, sulphite pulp, etc.

Automatic Weighe[r] Packaging Powders

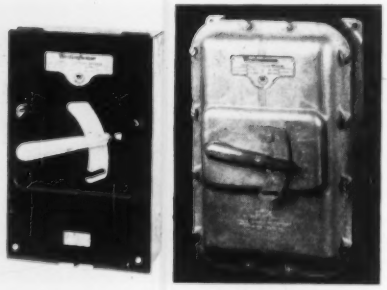
Toledo Scale Co. announces [the] organization of a combination of [scales] and other equipment (of its [own] other manufacture) whereby [bulk] flow-



ing material (granular, crystalline or powdered) is automatically weighed off into predetermined loads and each load automatically discharged into a bag, barrel or other container. Including a vibrator conveyor, a double photoelectric cut-off, a properly selected Toledo scale with long graduated beam and poise, and three hoppers each designed for its specific function, the new assembly combines a high degree of automaticity with a high degree of accuracy and is said to require little attention.

Circuit Breakers for Lighting and Power Circuits

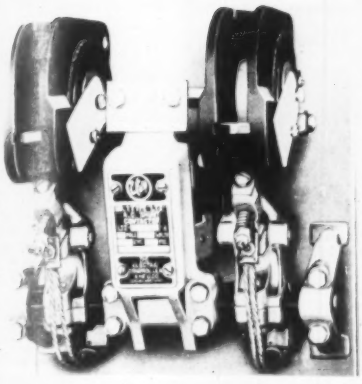
"Type AB-1 De-ion" circuit breaker has been developed by the Westinghouse Electric & Mfg. Co. to give individually enclosed circuit breaker protection for main services, light and power wiring systems. This device, requiring no element to renew after circuit interruption, provides a completely enclosed, non-tamperable unit to replace fuses, fused switches and other similar circuit pro-



tectors. These enclosed breakers require approx. 40% less mounting space than the conventional fused safety switch. The AB-1 breaker provides safety to the operator, as no live parts are exposed. Rating are 15-50, 50-100, 50-225 and 225-600 amp. either 250 volts a-c., 125/250 volts d-c., or 600 volts a-c., 250 volts d-c. On all frames except the 15 to 50 amp. size, the thermal and magnetic trip is built as a separate unit so that the breaker rating can be changed by changing the trip unit. Within the capacity limitations of the various frames, trip units are available in ratings corresponding to standard wire and cable sizes. These breakers can be furnished for practically all classes of service. All enclosures except grounded neutral enclosures have an external cast handle, self-indicating, that engages the molded breaker handle to facilitate ease of operation. Breakers can all be operated from outside the cabinet "on"—"off"—or "reset." Left-hand photo shows dust-resisting breaker; right-hand photo shows weatherproof model.

Pocket Spring Scale

In size as well as in appearance when closed, the new "Postalett" brought out by The Exact Weight Scale Co. resembles a fountain pen. (Both cap and barrel, however, are decagonal instead of smoothly cylindrical—to prevent rolling off.) To use, remove cap, hold scale vertically and suspend the object from the combination clip and eye. Capacity, 8 oz. Zero adjustment is readily accessible and requires no tool. Manufacturer's literature dwells only on convenience when used to weigh letters and circulars, but we believe that this first vest-pocket scale should find as many technical uses as has the pocket thermometer.



A-c. Magnetic Contactors

In last month's issue (page 315) an exclusive full description of the new "Line-Arc" d-c. contactors appeared. An a-c. line with similar features is now announced by The Electric Controller & Mfg. Co. Known as the EC&M Type LTZ Line-Arc Contactors, these units are of light-weight, quick-moving aluminum alloy construction said to provide an entirely new standard of high-speed operation. A full-floating, resiliently-mounted armature eliminates hum and chatter caused by uneven meeting of pole faces, cushions the slam on closing, and gives an added impetus in opening the contactor. Bearings are of the "Oilite" self-lubricating type, of self-aligning, spherical design making it easy where required to remount these contactors as part of switchboards and similar panels. Single-, double- and triple-pole models are available, arranged for terminal connection at front or rear of contactor base.

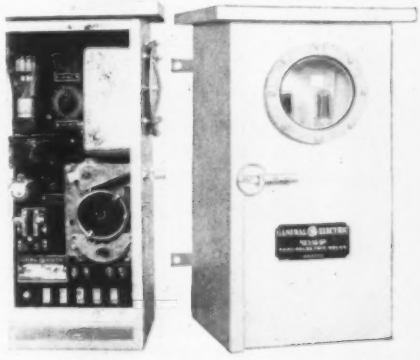
Mercury Tube Toggle Switch

The Hart Mfg. Co. announces a small compact switch operated by a noiseless toggle which tips a sealed mercury tube, making and breaking the circuit by the flow of mercury. Positive contact is assured; no exposed arc is possible; the switch may be used in moisture- or fume-laden air. It has been designed to meet special requirements of industrial and

illuminating engineers to overcome problems where a silent, non-exposed-arc, heavy-duty switch is needed: controlling lighting or motors in oil refineries, grain elevators, chemical and rubber plants and other locations where exposed arcing would be dangerous; also because of its noiseless operation in motion picture sound studios, etc. Non-inductive ratings: 30 amps. at 125 volts, 20 amps. at 250 volts, a.c. or d.c.; inductive ratings of same medium order.

Photoelectric Relay for Outdoor Lighting Control

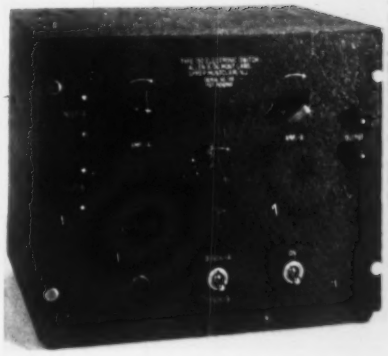
Independent "on" and "off" adjustments are among features of new Novalux photoelectric relay for control of outdoor lighting now available from the General Electric Co. This new relay, designated as the CR7505-H6, can be set to switch off at a lower intensity in the morning than that at which it turns on in the evening. This independent adjustment is accomplished by means of two potentiometer resistors and a time switch, the latter transferring control from one potentiometer resistor to the other at approximately noon and midnight. The relay can be set to operate, either for turning on or turning off, at any intensity between 0.1 and 10 footcandles. Two phototubes in parallel behind a larger window, instead of only one, provide this extended sensitivity range. Tools are not



required for checking and adjusting this relay. The phototubes are enclosed in a light-tight cover which makes it possible for the door of the case to be opened and the setting to be made readily by hand. The potentiometer resistors are easily accessible and are provided with large indicating knobs and graduated dials. Part-night operation of street lighting, floodlighting, electric signs, etc., is accomplished by setting the "off" rider on the time switch to the desired time and turning the "off" potentiometer resistor to the zero point on the dial. The advantage of photoelectric control for turning on the lighting is retained.

Electronic C-R.O. Switch

"Type 150" Electronic Switch announced by the Allen B. Dumont Labs. increases the value of the cathode-ray oscillograph by permitting simultaneous observation of any two voltage or current phenomena. This device can be used to inspect and compare the wave-form and phase of two voltages or currents from different parts of the same circuit or compare the wave-form of a standard wave and any other wave. Thus it is possible to see the input and output wave-form and phase displacement of an amplifier, or to apply a timing wave in conjunction with the wave under observation. The device has no mechanically moving or vibrating parts. It consists of a switching tube and two amplifiers, one for each phenomenon applied. The switching tube operates to cut in one amplifier, then the other at such a rate that



the two phenomena appear at the same time. In addition to switching the device also amplifies. Controls are provided for adjusting the gain of the amplifiers and for varying the speed of switching. The unit is supplied ready for use on 110-120 volts 60 cycle a.c.

Internal-combustion Engine Combustion Analyzer

Analyses of the exhaust gases of internal-combustion engines are quickly performed by means of the Allen Combustion Analyzer which the Allen Electric & Equipment Co. has brought out in two models: "Model G 30" (of which the upper part is illustrated) is mounted on a pedestal with casters, making it suitable for use around the service station; "Model G 31," designed for

road tests, measures 9½" x 13" x 5" and weighs 13 lbs. (slightly more in carrying case with sampling tube, etc.). The instrument panel of "Model G 30" is illuminated. It bears three indicators: (1) the main dial, graduated in fuel-air ratio and combustion efficiency with additional explanatory markings, (2) an ammeter for adjusting cell filament temperatures and (3) a small vacuum gage for checking condition of motor. For gas analysis the thermal conductivity method is employed: a continuous sample of the exhaust gases passes through one hot-wire cell (after passing through a small centrifugal water separator) while air passes through a reference cell of identical construction. Three to five minutes is the time required for a determination of combustion efficiency. Manufacturer reports endorsement of motor fuel companies.

NEW A high-speed semi-automatic gage acting as a comparator sensitive to millionths of an inch.
Electronic Inspection Laboratories
663 BANGOR BUILDING
CLEVELAND, OHIO

MANUFACTURERS' NEW LITERATURE

In this department we list each month the printed matter issued by manufacturers. Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter are invited to do so.

C342 **Industrial Analyzer.** Circular A-5000-A describes Model 639 industrial analyzer; also contains a diagram of internal connection as well as connection diagrams. Weston Electrical Instrument Corp., Newark, N. J.

C343 **Magnetic Chuck Rectifiers.** Bulletin 8651, for use with magnetic chucks, illustrates and describes a full-wave rectifier for obtaining rectified a.c. from 110-volt 60 cycle service, and lists 4 sizes covering a range up to 1800 watts. Ward Leonard Electric Co., Mt. Vernon, N. Y.

C344 **Surface Illuminator for Opaque Specimens.** Four-page leaflet D-192 gives description, illustrations, specifications and prices of this device. Bausch & Lomb Optical Co., Rochester, N. Y.

C345 **New Cathode Ray Oscillograph.** Type 148 Bulletin lists the exclusive features and the specifications of this new instrument. Allen B. DuMont Labs., Upper Montclair, N. J.

C346 **General Radio Equipment.** The Oct. 1935 issue of this house organ contains several interesting articles: Shielded Transformers for Impedance Bridges; Increased Accuracy with the Precision Condenser; and Residual Impedances in the Precision Condenser. General Radio Co., 30 State St., Cambridge A, Mass.

C347 **Combustion Analyzer.** Leaflet 970 illustrates a portable analyzer for floor or road tests on automobiles. Allen Electric & Equipment Co., Kalamazoo, Mich.

C348 **High Frequency Resistance Boxes.** Circular 322T gives a brief description and a-c. characteristics of these resistance boxes. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

C349 **Cathode-Ray Oscillograph.** Bulletin GEA-1768A is devoted to the Type HC-10-B1 oscillograph. General Electric Co., Schenectady, N. Y.

C350 **Vibration Counters.** A broadside illustrates 2 vibration counters for frequencies between 4 and 100 per second: one of these instruments is for high-tension transmission lines, and the other for machines, vehicles, bridges and other steel structures. R. W. Cramer & Co., Inc., 67 Irving Place, New York, N. Y.

C351 **Optical Protractor.** Bulletin D-231 shows the application of this instrument to a rapid and accurate method of measuring angles. Bausch & Lomb Optical Co., Rochester, N. Y.

C352 **D. C. Contactors.** File No. 8490 shows the features of the new Electric D.C. contactor. General Electric Co., Schenectady, N. Y.

C353 **Morrison Purifying Tube.** Four-page bulletin describes this tube as well as drying and absorbing agents. E. H. Sargent & Co., 155 E. Superior St., Chicago, Ill.

C354 **Frequency Oscillator.** 4-page folder gives a technical description and details of an all-wave a-f. and r-f. oscillator. Hickok Electrical Instrument Co., 10514 Dupont Ave., Cleveland, Ohio.

C355 **Owen Bridge for Magnetic Testing.** Circular 321, brief description of this instrument for testing sheet iron and steel. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

C356 **Sound Level Meter.** Single sheet illustrating the RA-198 sound level meter. Electrical Research Products, Inc., 250 West 57th St., New York, N. Y.

C357 **Electric Water Level Gage.** Bulletin 351 describes a self-contained electric water gage developed in cooperation with engineers of the United States Forest Service. It was developed to do the same work as the hook gage. R. C. Burt Scientific Laboratories, 211 Clay St., Pasadena, Calif.

C358 **Refrigeration Controls.** The Penn Electric Switch Co., Des Moines, Iowa, has just issued a revised and condensed catalog covering the principal types and models of their complete line of commercial, semi-commercial and domestic replacement refrigeration controls.

C359 **Bakelite.** The Bakelite Corp., River Road, Bound Brook, N. J., has issued a 40-page jubilee edition of its house organ, The Bakelite Review, to commemorate its 25th Anniversary. This issue traces the development and history of the company.

C360 **Ortho-Stereo Camera & Stereoscope.** Bulletin E-237 describes this new camera and stereoscope. Bausch & Lomb Optical Co., Rochester, N. Y.

C361 **Electrical Instruments.** Circular E-1-A, 12 page catalogue, which contains illustrations and brief descriptions of 57 Weston products. Weston Electrical Instrument Corp., Newark, N. J.

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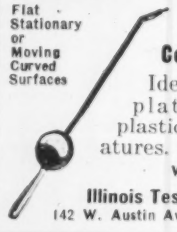

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A DIRECT-RECORD METHOD OF TIME STUDY

(Continued from page 321)

etc. Table I is an actual example of the subsequent steps in the standardization of relatively simple operations. It will be noted that the time of "Operator No. 12" on "cut f-h" varied from less than a fifth of a minute to more than one minute, whereas on cut "n-h" she never took as much as two-thirds of a minute or as little as half a minute in the ten observations made by the time study man. It will also be noted that the time study man deemed it unnecessary to time this operator more than once on "cut h-h" whereas he timed her 22 times on each of three other cuts. The factors which made him decide when to take one reading and when to take more than twenty were inherent in the simplicity or complexity of the tasks he studied, or in his previous acquaintance with the performance of "Operator No. 12" on a particular operation (such as "cut h-h" which he considered to be essentially a duplication of a cut of similar shape and approximately equal length in another style of garment made of the same cloth).

From even a casual inspection of Figs. 2 and 3 it is apparent that the time study man who uses an ascholiagraph can register overlapping processes—a feat almost impossible by the use of a watch. Other advantages have made themselves evident: He can keep his eyes constantly on the worker, never missing a single movement. He can time phases as short as a single second—another feat difficult by the use of a watch. Noting changes in work phases is reduced to the simplest terms of human behavior, the movement of a single finger. (Simple, single movements are always more rapid and more constant.) Most of the labor of making process charts is eliminated; the chart is there whether it is needed or not. All the advantages of stop watch procedure are still retained. One man will take as many data as five men using stop watches, using an instrument costing less than five good stop watches, and reducing the labor to less than one-tenth of the old method, for records which are more precise.

AUTOMATIC CONTROL OF PUMPS

(Continued from page 319)

results. But frequent clogging of orifice and loss of air in the tank have resulted in a demand for a more reliable means of control by a pressure actuated instrument.

In an effort to effect the possible economies of automatic operation, there has recently been developed a controller equipped with an electrical "snubber" which eliminates the effects of surges on the controller. It may be used in conjunction with time-clock control so set that the pumping operation will be carried on during off peak hours of power consumption and will also maintain a full reservoir up to any predetermined hour. Adjustment may be provided for protection against depletion of supply, even during "prohibited" hours, should emergency arise.

The standard controller which is used for single pump elevated tank systems has two pressure switches or units for low and high levels respectively. Thus it is possible to adjust either unit independently of the other, which permits any differential between high and low levels.

The "snubber" consists of a bimetallic strip, a heating coil wound around it and a mercury switch attached to its end. Heating the coil causes the bimetallic strip to warp, thereby tilting the mercury switch to the "open" position; when the strip cools, the mercury switch returns to "closed" position.

The snubber switch serves the same function as the "stop" switch in a push-button station. This is illustrated in Fig. 1 which shows how a push button station is wired to an automatic motor starter and how the snubber switch and low-level pressure switch of this controller serve the same functions as the push button station.

Closing the low-pressure switch of the controller corresponds to pushing the "start" button. Opening the snubber switch produces the same results as pushing the "stop" button. When the motor is once started, the "start" switch may be dropped; for the same reason the low-pressure switch of the controller may be broken without affecting the pump. Thus the starting surge effects are eliminated from the starting circuit.

The "stop" circuit cannot open to stop the motor, due to the time delay effect of the snubber. In other words, the high-level pressure switch must be closed long enough to heat the snubber strip to the point of opening the snubber mercury switch. Although the surges make and break both low- and high-level switch, the contacts are momentary and therefore not sufficient to heat the snubber.

As shown in Fig. 2, the high-level pressure switch closes when high level is reached and energizes the heating element of the snubber. Under influence of heat, the bi-metallic strip warps and in about fifteen or twenty seconds the snubber ("stop") switch opens and pump shuts down. Stopping surges do not affect the controller since the snubber switch will remain open for about two minutes, which provides enough time for the surges to be dissipated; it is necessary for this switch to be closed before the pump can start.

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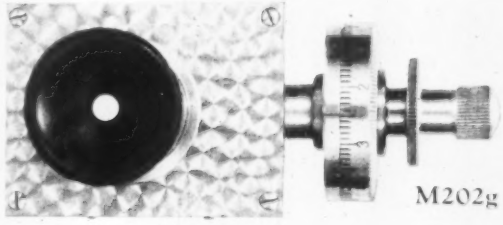

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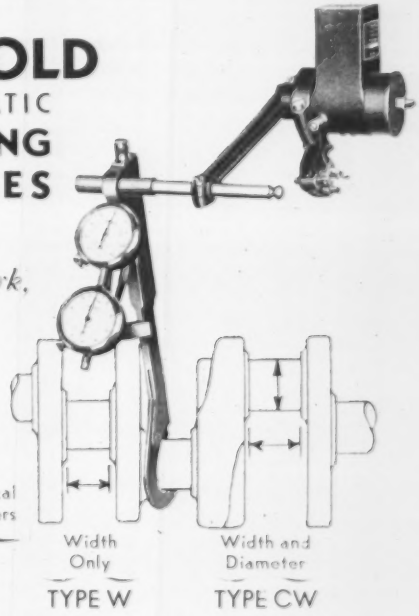

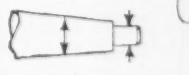

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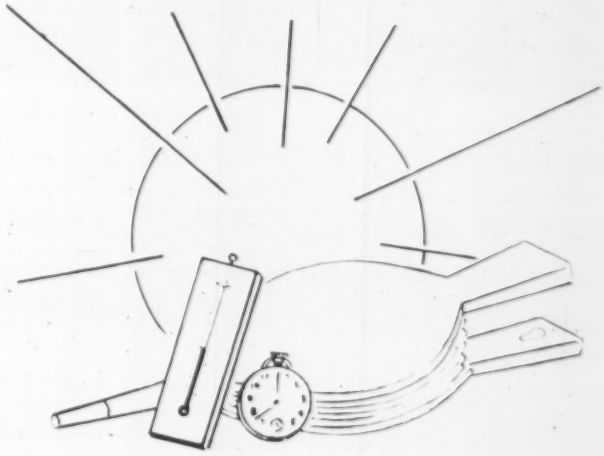

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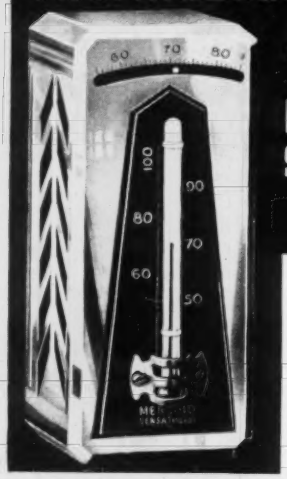

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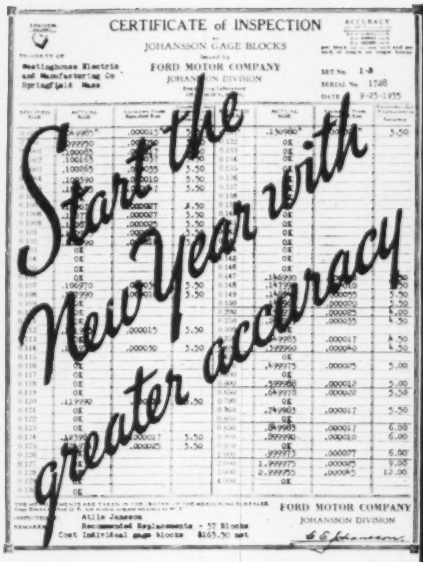
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SURFACE AQUASTAT

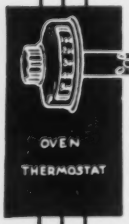
IMMERSION THERMOSTAT

We specialize on commercial type of equipment for water heaters, ranges, ovens, incubators, etc.

You will find the design the very last word in simplicity—The workmanship and adjustment that of skilled artisans who are proud of their work—deliveries are usually prompt.

Let us know your wants and we will do our best to satisfy you.

Send for our interesting Bulletins on Thermostats.


OVEN THERMOSTAT

MERCURY TUBE THERMOSTAT

STRUTHERS DUNN, INC.
(Manufacturing Specialists of Control Equipment)
125 N. Juniper St., Philadelphia, Pa.

DUNCO

Get All These Features When You Visit CHICAGO

A MICHIGAN AVENUE LOCATION
RIGHT AT THE EDGE of the LOOP
MODERN SPACIOUS ROOMS
FOOD THAT IS WORLD FAMOUS
EFFICIENT, COURTEOUS SERVICE

LOW RATES
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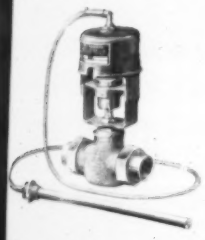
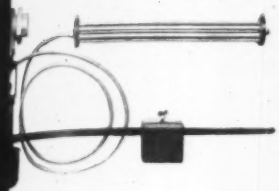
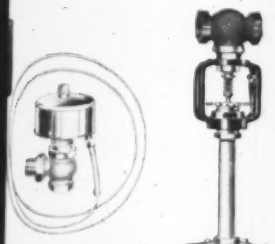
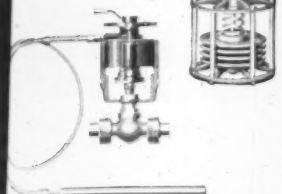
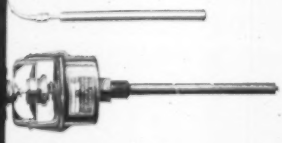
Self
erated Controls



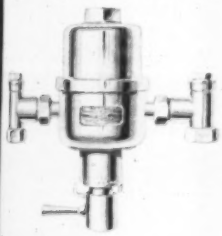


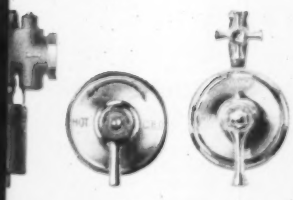


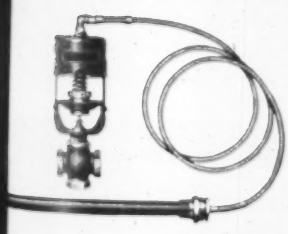




rmostatic Mixing Valves
acities ½ to 2650 Gal. per Min.







Which Type of Control

Pneumatic or Self Operated

Will Give the Results You Want at the Lowest Cost?

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Before you buy either type of control, investigate the possibility of getting reliable regulation and of saving money with a Powers self operated regulator. Some of their many advantages are:

> Low first cost, simplicity and durability, lower operating and maintenance cost, easy installation, ability to withstand vibration and usage which might interfere with the performance of more delicate and extremely accurate controls—these are some of the reasons which make Powers self operated regulators economical wherever they can be used.

With 45 years of experience in furnishing and installing temperature and humidity control for every conceivable purpose, we have gained a wealth of experience from which you can draw in selecting the proper type of control for any purpose.

● The Powers Regulator Co., Offices in 43 Cities — See your phone directory. 2720 Greenview Ave., Chicago — 231 East 46th St., New York — 1808 West 8th St., Los Angeles — 105 Lombard St., Toronto, Ontario, Canada.

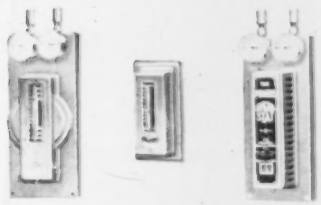
POWERS

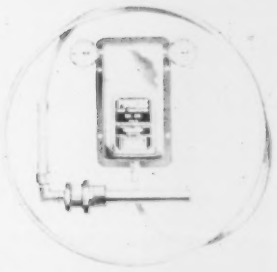
TEMPERATURE • HUMIDITY and AIR FLOW CONTROL

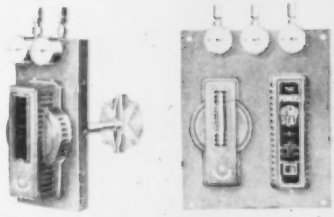
for

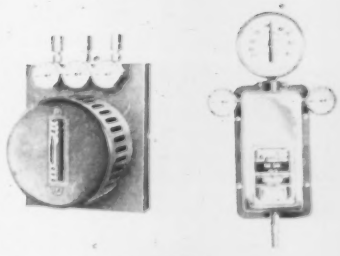
eating • Cooling • Ventilating and Air Conditioning Systems and Industrial Pr

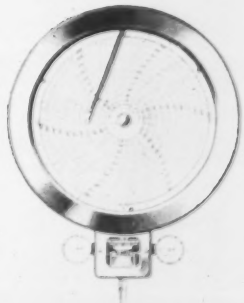
Air
Operated Controls

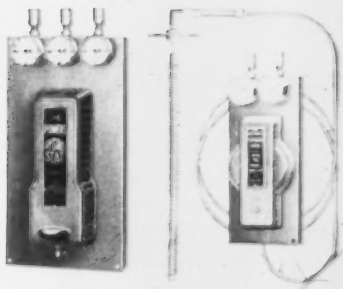




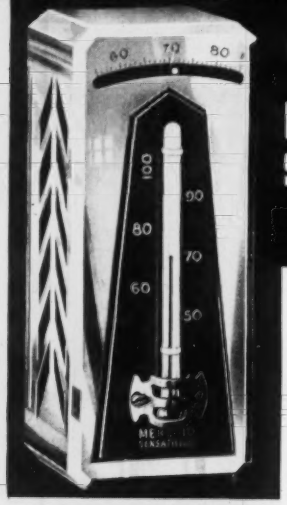








"WE USE CHACE
Thermostatic BIMETAL
Exclusively
IN THE
MERCOID
SENSATHERM"
THE MERCOID CORPORATION

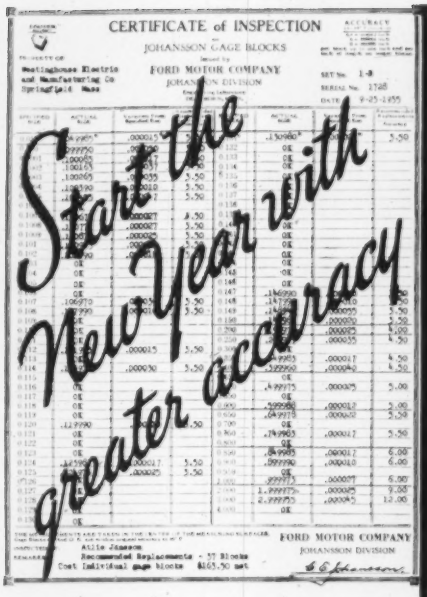


With the slightest change in temperature, highly sensitive Chace Thermostatic Bimetal units move to make or break electric contact, thus automatically setting to action such other mechanism as results in room temperatures exactly to our liking.

If control of temperature is your problem or if you wish to have temperature changes perform automatic duties we suggest that you investigate Chace Thermostatic Bimetal. *Sold in Sheets, Strips or Formed to Specifications.*

CHACE THERMOSTATIC BIMETAL
"It Bends with the Heat"

W. M. CHACE VALVE CO.
1609 Beard Avenue - - - Detroit Mich



This is the Certificate of Inspection you will receive. It shows the accuracy of each block with the wear indicated in millionths of an inch. The cost for this service is very nominal—only 20 cents for blocks 1 inch long, and for longer blocks 20 cents per inch of length.

JOHANSSON
GAGE BLOCKS and ACCESSORIES

Manufactured, sold and serviced in the United States and Canada by

FORD MOTOR COMPANY
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HAVE YOUR JOHANSSON GAGE BLOCKS INSPECTED NOW

INSURE HIGH STANDARDS OF PRECISION IN 1936

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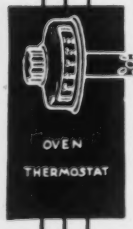

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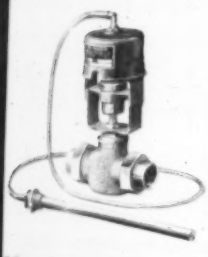

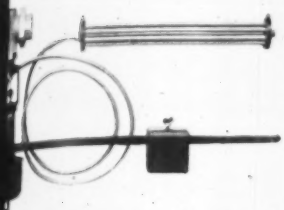

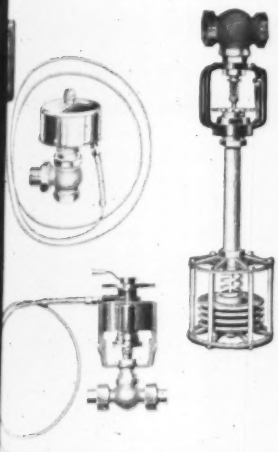

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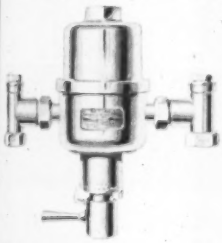

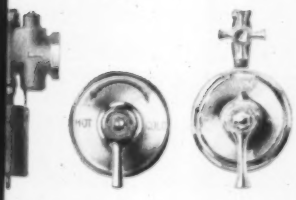

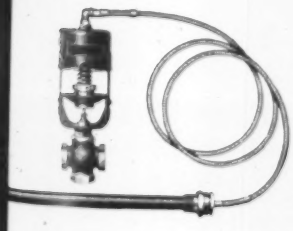

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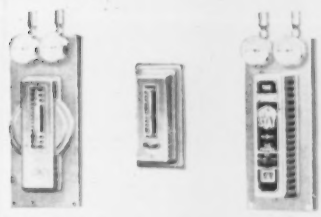
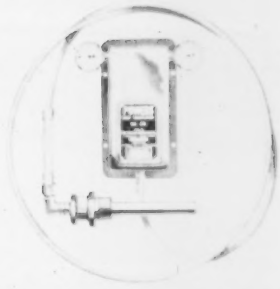
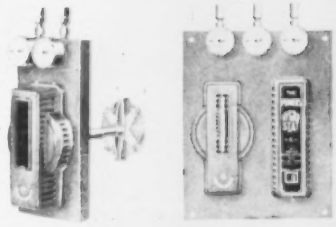
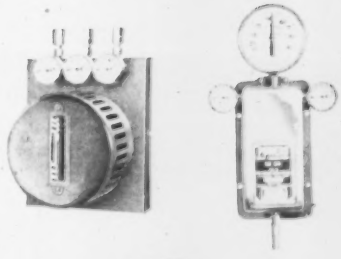
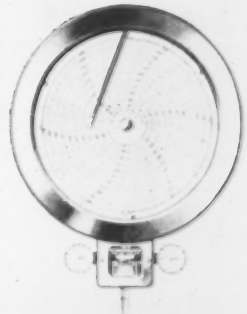
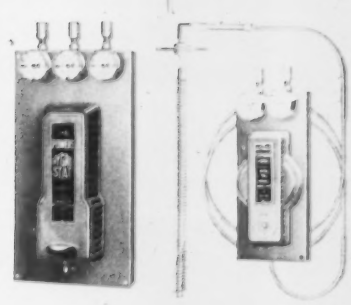




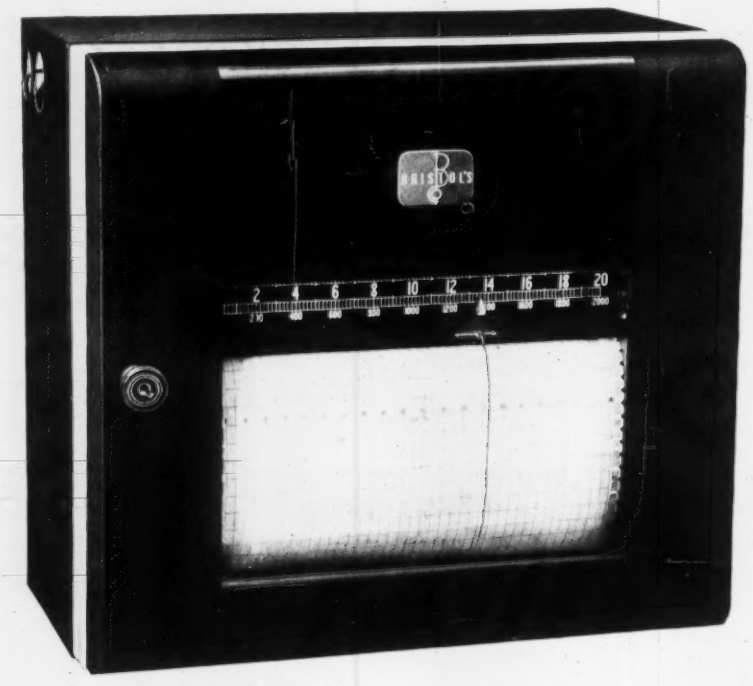








Industry Acclaims *this fine pyrometer*

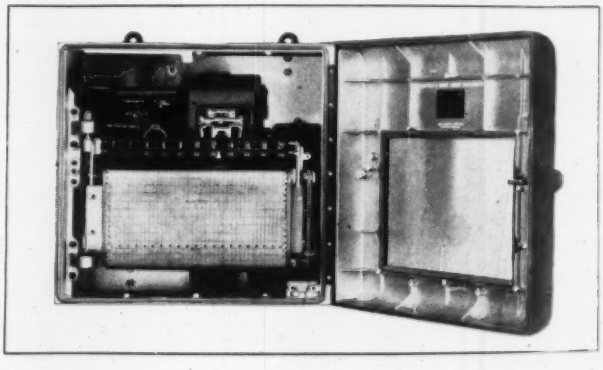


Built by the pioneer makers of Pyrometers, this latest Bristol's sets a new standard in potentiometer design and craftsmanship

Only a mere month or so has elapsed since this new Bristol's Wide-Strip Pyrometer was first announced at the Chicago National Metal Congress in October. Yet according to the ever-increasing number of enthusiastic reports that are coming in, it is the finest pyrometer ever presented to industry! Again Bristol design and craftsmanship have triumphed!

The use of a new principle in the balancing mechanism permits even the smallest deflections of the galvanometer to be measured and recorded. The pen responds promptly. Balance is quickly restored. Changing temperatures are speedily and accurately charted. Thanks to the elimination of back lash, lost motion, irregularities and the uncertainties unavoidable with friction wheels, ratchets and the like, this Bristol's sets a new standard in simplicity.

There are many features which merit careful appreciation. Besides the unusually wide strip chart, "far vision" indicating scale, heavy duty galvanometer, duplex-slide wire, these are fully described in Catalog 1450 mailed on request. Write for a copy.



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Branch Offices in Principal Cities. Canada: The Bristol Co. of Canada, Ltd., Toronto. England: Bristol's Instrument Co., Ltd., London, S.E.11

BRISTOL'S

TRADE MARK REG. U.S. PAT. OFF.

WIDE-STRIP POTENTIOMETER PYROMETER